ANALYSIS/DEMONSTRATION

OF

ADVANCED AIR TRAFFIC CONTROL CONCEPTS

APRIL 1, 1988

SUBMITTED TO:
UNITED STATES AIR FORCE
ELECTRONICS SYSTEMS DIVISION
HANSCOM AFB, MA 01731
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CONTRACT NO.
F19628-87-C-0254

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CAGE NO. 4A454

ANALYSIS & COMPUTER SYSTEMS, INC.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1988 Apr 01	FINAL

4. TITLE AND SUBTITLE
Analysis/Demonstration of Advanced Air Traffic Control Concepts

5. FUNDING NUMBERS
F19628-87-C-0254

6. AUTHOR(S)
Multiple

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Analysis & Computer Systems, Inc.
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Bedford, MA 01730

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Hq Electronic Systems Divisions XR
Hanscom AFB, MA 01731-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
[illegible]

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The original work plan for this study envisioned the linear sequence of activities shown in figure 2, a schedule prepared in August, 1987, before the contract was awarded. As the study evolved, however, tasking followed much more of an iterative path than a sequential one. These iterations were strongly driven by the demonstration scenario development. Analyzing the real time activities of aircraft under simulated ATALARS control highlighted the information that needed to be exchanged. Further, since the EJSE is designed to be a JTIDS network participant, the JTIDS message requirements for ATALARS were quickly identified, because the messages are the most readily available vehicle for information exchange between controlled aircraft and the ground controller. Finally, even the process of identifying the ATALARS algorithms became easier when analysts could assess situations which would evolve on the EJSE.

14. SUBJECT TERMS
ATC, air traffic control, advanced, concepts, ~~JTIDS~~, data link, communication, military, ~~ATALARS~~, ~~EJSE~~, decision support, ~~AI~~, algorithms, flight plan

15. NUMBER OF PAGES
73

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

SUMMARY

This Small Business Innovation Research (SBIR) study was initiated under Contract No. F19628-87-C-0254 to review and refine a concept called the Automated Tactical Aircraft Launch and Recovery System (ATALARS). The major product is a specification for a proof of concept demonstration which consists of two parts: this report and a model of the demonstration scenario capable of being run on ACSI's Enhanced JTIDS System Exerciser (EJSE).

ACSI has made a preliminary investigation of the potential use of ATALARS as the solution to the Air Traffic Control (ATC) requirements of the year 2000 and beyond. During this study, ACSI has begun to refine the ATALARS concept and has specified how a proof of concept demonstration could be performed during Phase II, by modifying subsystems of ACSI's currently available Enhanced JTIDS System Exerciser.

The results of the study are described in the following pages. The study shows that the Joint Tactical Information Distribution System (JTIDS) can perform as the ATALARS data link and can provide much of the desired indirect surveillance in a tactical environment. Further, ACSI has determined that implementing a subset of ATC algorithms on the EJSE can provide an effective proof of concept demonstration in a simulated real-time environment. ACSI can perform this proof of concept demonstration as a SBIR Phase II effort.

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1.1 ATALARS Concept.

The ATALARS concept envisions a radical change in the manner in which air traffic control is performed. In lieu of the conventional voice and radar based systems, ATALARS proposes the use of indirect surveillance, an automatic data link and automated management and control to provide the following services:

1. Area Airspace Management
2. Approach Control
3. Landing Control
4. Departure Control
5. Information Advisories
6. Tactical System Interoperability

As its name implies, the emphasis of ATALARS is on activity in the terminal environment. However, due to the close proximity and number of airfields in some of the areas where ATALARS will be used, it will have to be able to manage all ATC activity in its assigned airspace.

The ATALARS concept is described in detail in a paper titled "Advanced Air Traffic Control Concept" (ESD-TR-86-259) by St. Sauveur and Hughes, dated 19 June 1986. A diagram showing the major components of the ATALARS concept and their interrelationships is shown in figure 1.

1.2 Technical Objectives.

In the proposal for Phase I, four technical objectives were set for this effort. They were reviewed and affirmed at the outset of the study, and are listed below:

1. Define at least a subset of the algorithms/rules required to support an automated ATC capability for a single ATALARS Ground Control Unit (GCU).

2. Define the data set communications requirements (information contents) required to support an automated ATC capability. These will be defined in terms of specified JTIDS messages.

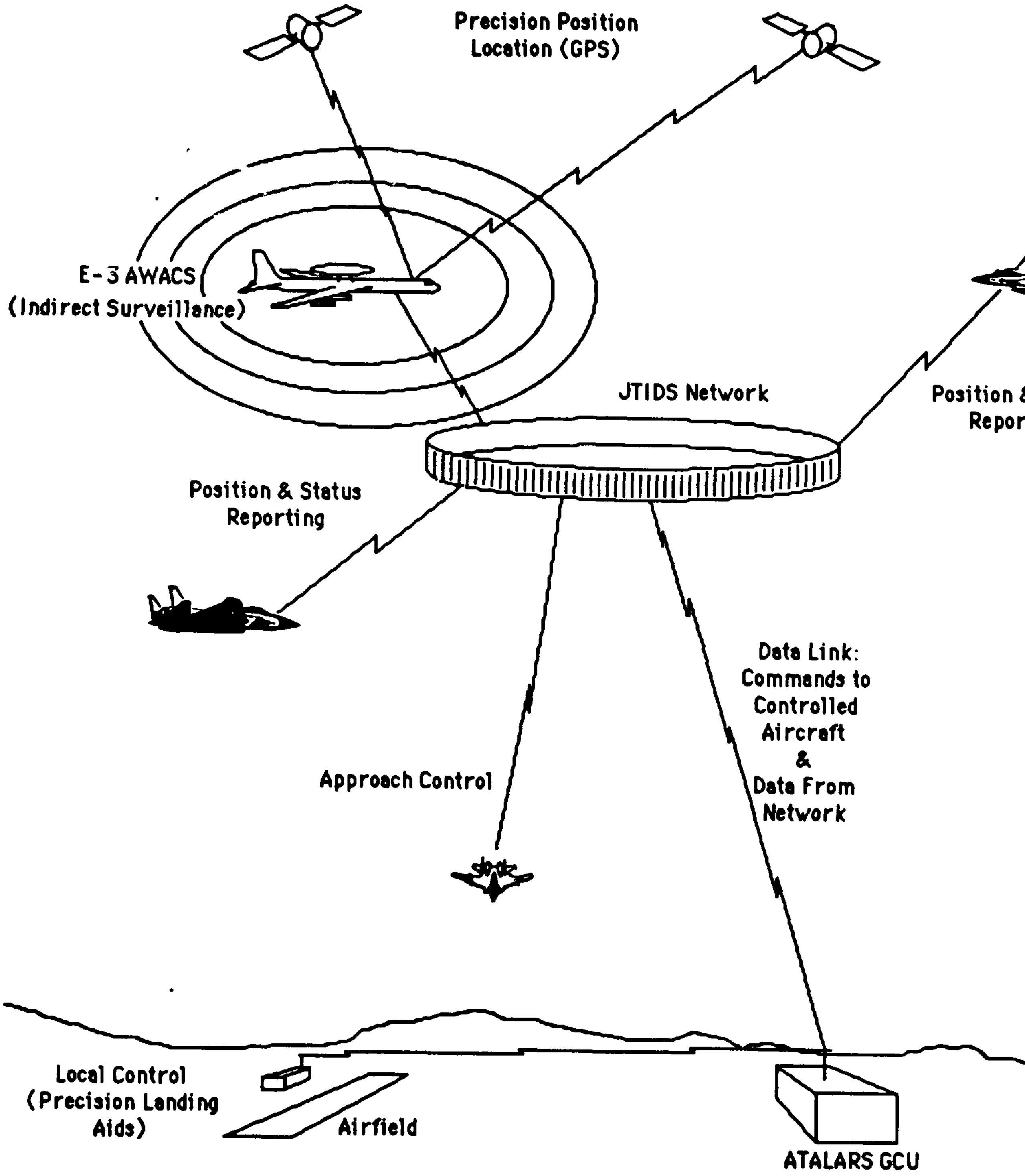


Figure 1
<u>ATALARS CONCEPT</u>

3. Identify the modifications to the EJSE required to support a demonstration of the automated ATC capability in accordance with the algorithms/rules and communication requirements defined above.

4. Define a Preliminary Operational Scenario which will form the basis for simulation and test in the SBIR Phase II study.

Although this study addressed most of the ATALARS services, the emphasis was on the decision aids to be employed in the GCU computer (referred to as the "ATALARS Processor" in this report) and on the extent to which the JTIDS data link can support the ATALARS services. As a result, precision landing aids such as the Microwave Landing System (MLS), and other navigation aids which would support indirect surveillance, such as the Global Positioning System (GPS), were not covered in any depth.

1.3 Study Approach.

The original work plan for this study envisioned the linear sequence of activities shown in figure 2, a schedule prepared in August, 1987, before the contract was awarded. As the study evolved, however, tasking followed much more of an iterative path than a sequential one. These iterations were strongly driven by the demonstration scenario development. Analyzing the real time activities of aircraft under simulated ATALARS control highlighted the information that needed to be exchanged. Further, since the EJSE is designed to be a JTIDS network participant, the JTIDS message requirements for ATALARS were quickly identified, because the messages are the most readily available vehicle for information exchange between controlled aircraft and the ground controller. Finally, even the process of identifying the ATALARS algorithms became easier when analysts could assess situations which would evolve on the EJSE.

Another difference in the actual conduct of the study was that the modifications required for the EJSE to perform the proof of concept demonstration were apparent from the start, so this part of the study was able to be done on a parallel path. The revised and approved schedule, shown in figure 3, reflects the changes in

Figure 2

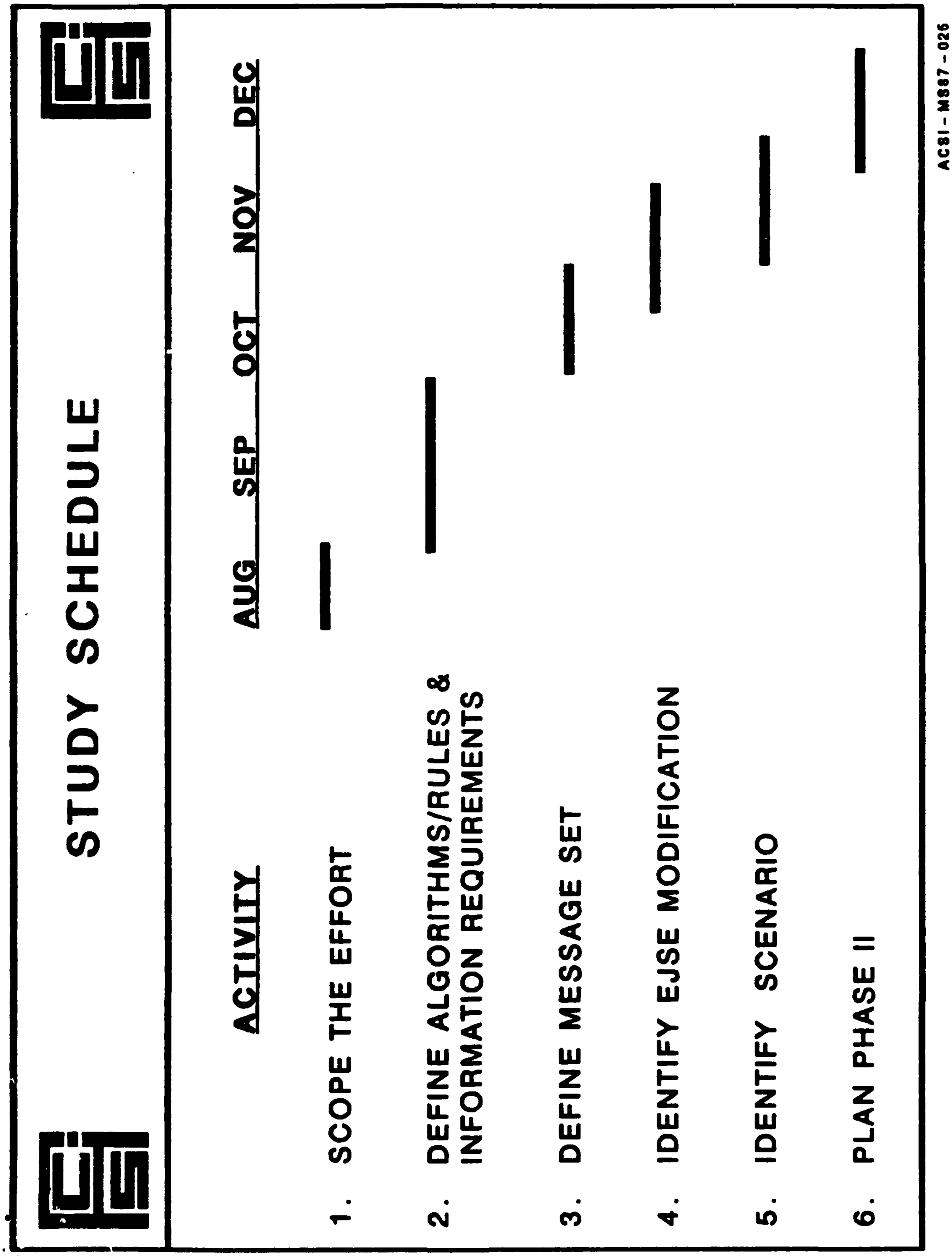
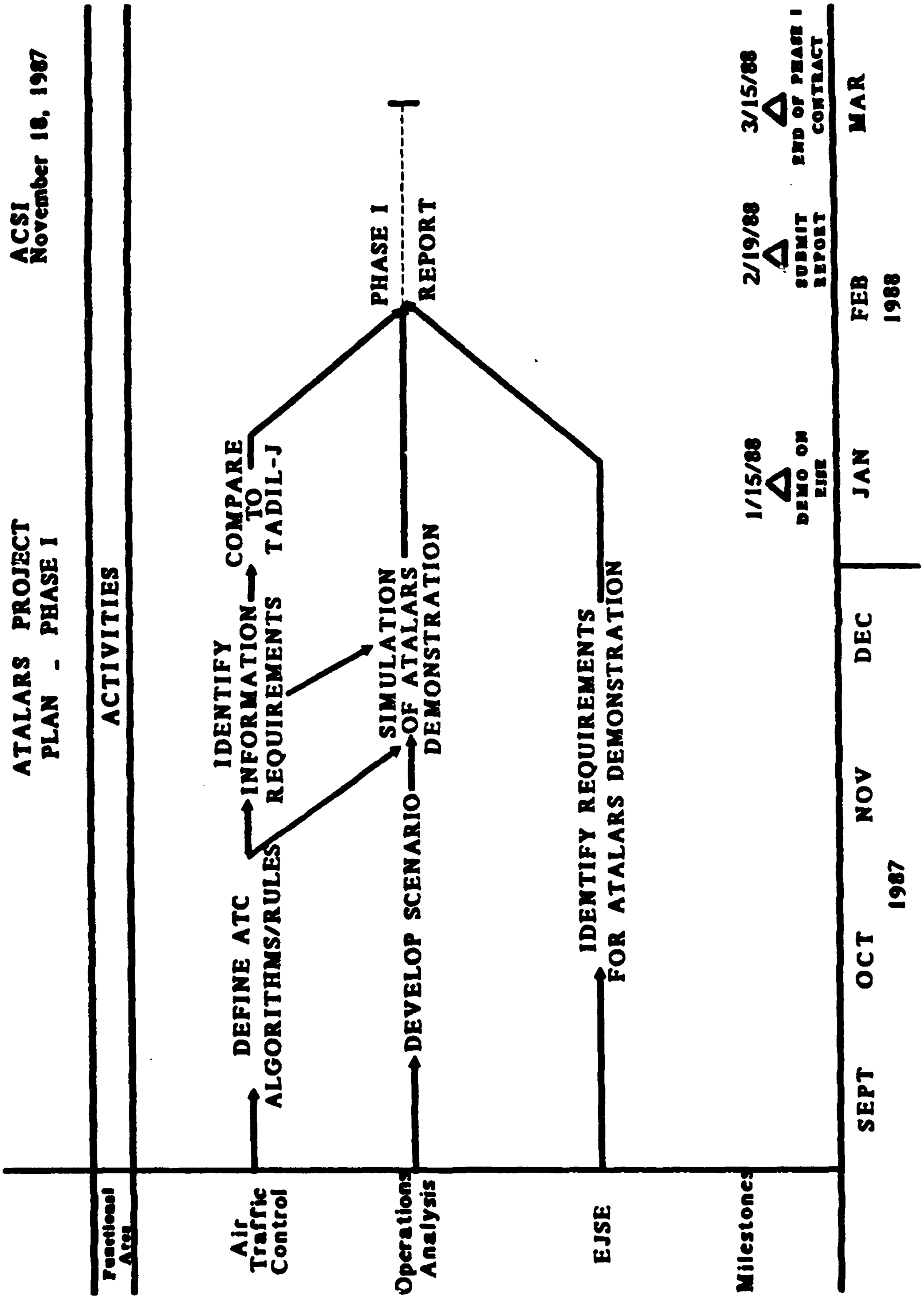

STUDY SCHEDULE
ACTIVITY
AUG
SEP
OCT
NOV
DEC
1. SCOPE THE EFFORT
2. DEFINE ALGORITHMS/RULES & INFORMATION REQUIREMENTS
3. DEFINE MESSAGE SET
4. IDENTIFY EJSE MODIFICATION
5. IDENTIFY SCENARIO
6. PLAN PHASE II
ACSI-M887-026

Figure 3


ATALARS PROJECT
PLAN - PHASE I
ACSI
November 18, 1987
ACTIVITIES
Functional Area
Air Traffic Control
Operations Analysis
EJSE
Milestones
DEFINE ATC ALGORITHMS/RULES
IDENTIFY INFORMATION REQUIREMENTS
COMPARE TO TADIL-J
DEVELOP SCENARIO
SIMULATION OF ATALARS DEMONSTRATION
PHASE I REPORT
IDENTIFY REQUIREMENTS FOR ATALARS DEMONSTRATION
1/15/88
DEMO ON EJSE
2/19/88
SUBMIT REPORT
3/15/88
END OF PHASE I CONTRACT
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
1987
1988

task sequence.

Since the primary intent of this study was to specify a proof of concept demonstration, one of ACSI's first objectives was to narrow the focus of the study to deal with a specific aspect of Air Traffic Control. The intent was to select an aspect of ATC which would provide highly visible results when demonstrated during the SBIR Phase II activity, so it would be clear to anyone observing the demonstration that the model ATALARS Processor was working. Initially, the collision avoidance aspects of the Area Airspace Management service seemed to present the best opportunity to do this. A scenario could be set up which would result in a collision if left to run as started, but when the simulated GCU was activated, it would vector the two aircraft that are on a collision course to safe headings and/or altitudes. Although this capability will be included in the Phase II demonstration, it became apparent during the study/investigation that collision avoidance may not be a major concern for the ATALARS Ground Control Unit after the year 2000. With the indirect surveillance and automatic data link capabilities implicit in the ATALARS concept, and on board support systems such as the "Pilot's Associate" being developed for the Advanced Tactical Fighter, each aircraft would have a cockpit display which would warn its pilot of the impending danger and recommend a course of action, thus allowing the pilots themselves to take evasive action without any inputs from the Ground Control Unit. However, the Ground Control Unit would retain an active role in highly constrained or congested airspace as well as in situations where one or both aircraft are not equipped with the ATALARS data link.

The next choice for demonstration of the concept was Landing Control. Although not as dramatic as collision avoidance, it did provide interaction between the Ground Control Unit and the aircraft. As the study proceeded and work began to identify and define a set of algorithms and rules for providing the ATC Landing Control services, it was found that decreasing the area under control produced simulation results exactly opposite to

what were hoped for. Limiting the analysis to final approach and landing produced results which were "quick and jerky" and not reflective of true aircraft operations. This is because the small distances involved caused radical changes to the simulated aircraft's motion when correcting even minor deviations from the planned route. Also, it was found that indirect surveillance and the automatic data link capability currently provided by JTIDS may be insufficient by themselves to land an aircraft in conditions where the pilot has no visibility. A pilot cannot proceed past the Missed Approach Point to touchdown by following instructions to go from point to point as they are received over a data link. Therefore, the focus of the study was expanded to cover Approach Control and the Approach Control aspects of Area Airspace Management, Landing Control and Information Advisories, which were found to comprise a major share of the controller's workload.

To accomplish this study, ACSI assembled an ATALARS research team consisting of a small nucleus of people who are highly capable in the fields of interest. First were pilots and people with related ATC experience. They provided their experience and guidance in establishing an initial set of the rules/algorithms required for demonstrating the ATC functions of the ATALARS concept. In addition, they defined the information needed by the pilot and by the Ground Control Unit for subsequent comparison to the JTIDS message set. The next group was the operations analysts who created the scenario and performed the comparison of information required to what is available in the JTIDS Tactical Data Information Link (TADIL-J) Technical Interface Design Plan (TIDP). The last group wa the systems engineers who worked on the ATALARS concept and established the approach for the proof of concept demonstration on the EJSE.

2.0 STUDY RESULTS

This section describes the results of ACSI's Phase I ATALARS study. They are arranged in the same sequence as the technical objectives described earlier:

1. ATALARS Algorithms
2. Data Set Communications Requirements
3. EJSE Utilization for Proof of Concept Demonstration
4. Scenario

2.1 ATALARS Algorithms

2.1.1 Introduction. The identification and quantification of the rules, algorithms and data needed to automate ATC functions proved to be the most time consuming part of the study. First was the issue of complexity. At one extreme, a properly briefed pilot who has filed a flight plan and is flying a properly instrumented aircraft can complete a flight with virtually no interaction with the ATC. At the other extreme is the situation faced by ATC in a tactical situation: multiple airfields of varying capabilities, dozens of aircraft taking off, landing and transiting within the controlled airspace, and numerous deviations to flight plans resulting from combat.

Next was the issue of the nature of the algorithms themselves. The ATALARS software will consist of a mixture of table look-ups or data base functions, decision rules or Artificial Intelligence (AI) functions, and optimization routines to establish priorities among incoming aircraft when some are damaged, low on fuel or otherwise incapable of following their original flight plans.

The algorithms identified and discussed in this study are relatively straightforward. However, the architecture envisioned for the system will support the more sophisticated functions and algorithms as the ATALARS concept matures.

2.1.2 Roles of Pilots and Controllers. In order to develop the algorithms and rules which must be employed by ATALARS, the roles of the pilot and ground controller in the present ATC environment

had to be evaluated. This section addresses the relationships that must exist between pilots and controllers, the basis for those relationships and the control information required by each community.

The role of any pilot encompasses three actions or responsibilities. In order of precedence they are:

1. Aviate - Operate the aircraft in such a manner that will attain the desired mission safely.
2. Navigate - Know the aircraft position and altitude relative to a known reference at all times.
3. Communicate - Advise pertinent authority of the aircraft position, altitude, speed, status and the pilot's intentions, as required.

Technology now provides the pilot with many automated functions to determine and relay aircraft data, thereby freeing him to concentrate on his number one priority : Fly The Aircraft. Good examples of this are some of the automatically reported data provided by JTIDS. The Precise Participant Location & Identification (PPLI) message tells all participants in the JTIDS network the aircraft's location, speed, altitude, course, and Selective Identification Feature/Identification Friend or Foe (SIF/IFF) codes, as well as a wide variety of other information about the aircraft and its activity. The Air Platform Status message provides a similar amount of information about the status of the aircraft, its systems and its weapons. The JTIDS data link is intended to continue functioning under wartime conditions where present methods of air traffic control data automation may be degraded or compromised and would, therefore, be unavailable to the pilot and to the ground controller.

Air Traffic Control is a service that exists to promote the safe, orderly and expeditious flow of air traffic. The essence of ATC is the establishment and maintenance of appropriate amounts of separation between aircraft, such as those found in FAA Order 7110.65, Air Traffic Control. Safe separation is maintained by ATC through the monitoring of flight performance and the issuing

of advice/ direction to the pilot. ATC must, therefore, under all conditions, have aircraft situational parameters immediately available for all aircraft within its controlled airspace, and have means of communicating advice or direction necessary for safety of flight to pilots and other ATC facilities. Since military aircraft frequently share the same airspace used by civilian aircraft, ATALARS must be compatible with the requirements of civil aviation as well as military aviation.

From the viewpoint of civil aviation in the continental United States, airspace is generally considered to be either controlled or uncontrolled. Controlled airspace starts at either 700 or 1200 feet altitude depending on geographic considerations and continues in various forms to 60,000 feet altitude. All flight is uncontrolled above 60,000 feet. Civilian flights will always be considered to be under ATC requirements. Tactical portions of military flights are generally not subject to ATC requirements regardless of their location or altitude. Foreign airspace is categorized in a similar manner. This study of the ATALARS concept focuses on that portion of flights that occurs within controlled airspace during the non-tactical portion of their missions. Figure 4 is a diagram of U.S. controlled airspace, followed by definitions of the various airspace categories in Table I.

Controlled airspace is divided vertically and horizontally by function and environment. These areas are delineated in the Federal Aviation Regulations (FAR) and the Airman's Information Manual (AIM). They are further functionally detailed by Instrument Approach Procedures (IAP), also known as Approach Plates, and Enroute Navigation Charts and are supported by various specific mission oriented publications. Two representative Approach Plates are shown in figure 5.

Controlled airspace is also divided by aircraft operations occurring within that airspace. Aircraft are either in the Enroute or Terminal environment. Each environment has unique communications, performance and procedural requirements, but

Figure 4

CONTROLLED AIRSPACE

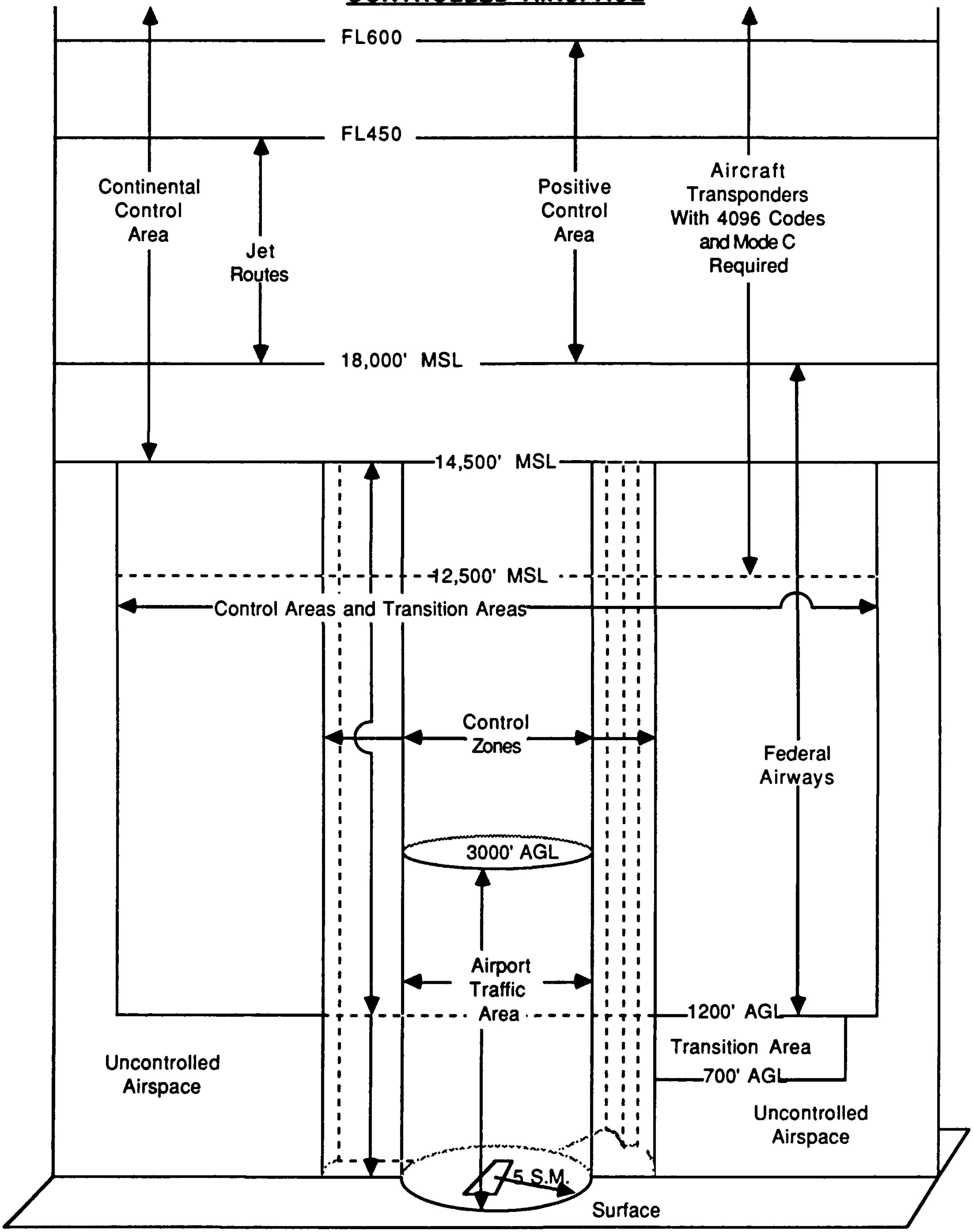


TABLE I

DEFINITION OF AIRSPACE CATEGORIES

AGL	Above Ground Level
FL	Flight Level (feet x 100) (used to define altitudes $\geq$ 18,000 ft.)
MSL	Mean Sea Level
S.M.	Statute Miles
Continental Control Area	The Continental Control Area consists of airspace above 14,500 feet, or 1,500 feet above surfaces higher than 14,500 feet, of the 48 contiguous states and part of Alaska.
Control Areas	Control Areas include the airspace associated with all federal airways.
Control Zone	A Control Zone extends from the surface up to the Continental Control Area and includes one or more airports. The control zone is normally a circular area within a 5 mile radius and may include extensions necessary for instrument approaches or departures.

TABLE I

DEFINITION OF AIRSPACE CATEGORIES - (Cont'd)

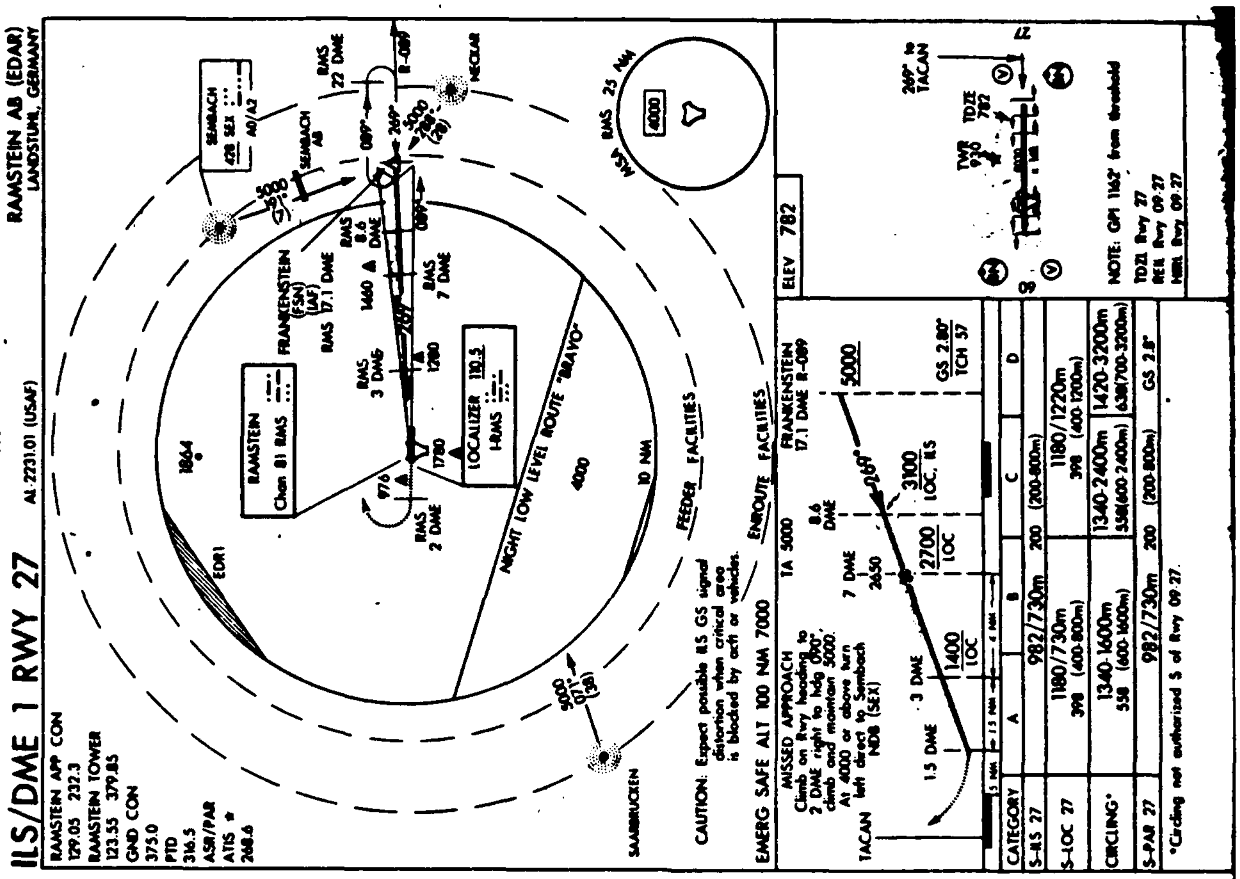
Terminal Control Area (TCA)	A Terminal Control Area is controlled airspace which requires all aircraft to comply with special operating rules and equipment requirements. The airspace extends from the surface to specified altitudes in the TCA. The lateral limits of the TCA are based on distance from the primary airport, and may have greater lateral limits at higher altitudes.
Positive Control Area	Positive Control Area is designated in the 48 contiguous states and parts of Alaska as airspace within which all aircraft are subject to operating requirements.
Transition Areas	Transition Areas are designed to contain IFR operations in controlled airspace transitioning the terminal and en route environments. These airspace designations extend from 700 feet, in conjunction with an instrument approach or 1,200 feet in conjunction with an airway, upward to the base of the overlying controlled airspace.

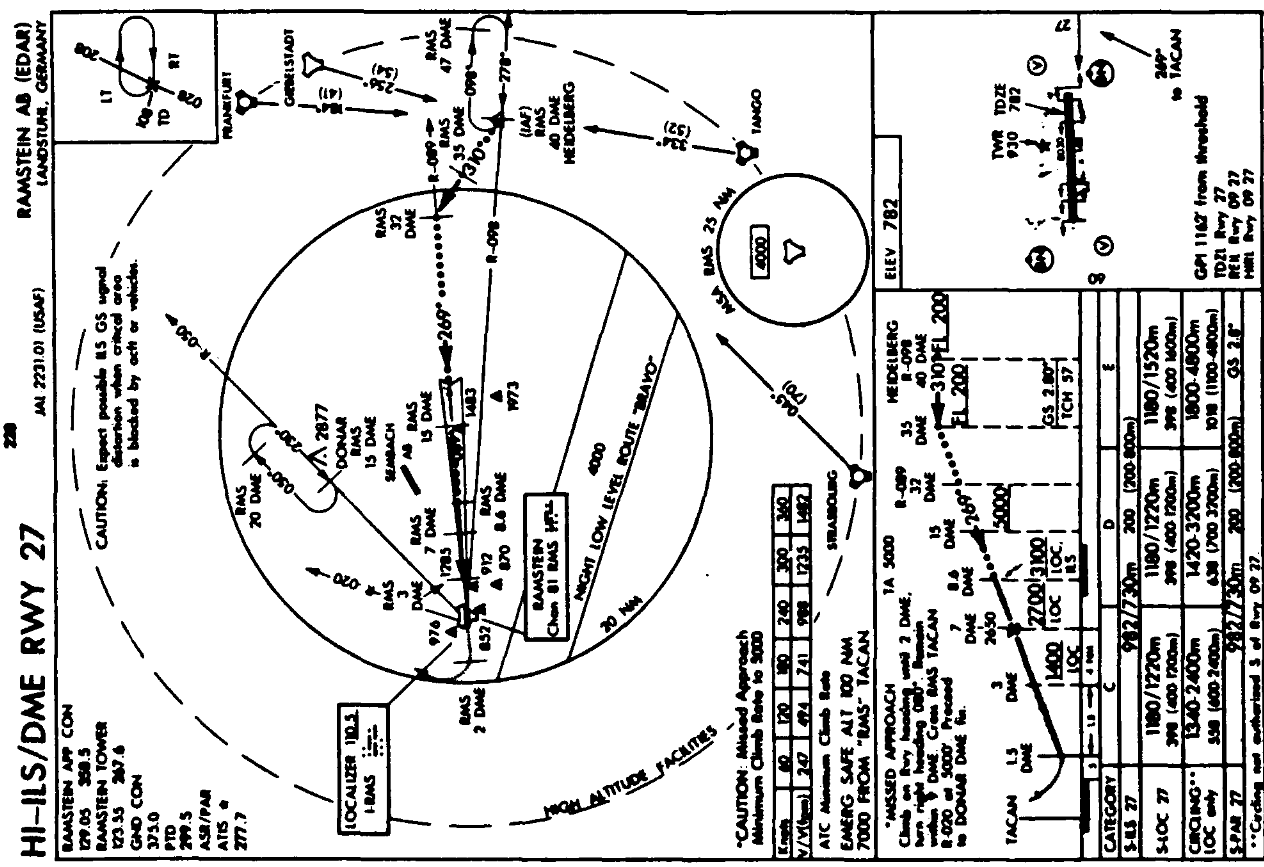
TABLE I

DEFINITION OF AIRSPACE CATEGORIES - (Cont'd)

Special Use Areas	In addition to controlled airspace there are several special use areas. These areas are Prohibited Areas and Restricted Areas. Prohibited Areas are defined as areas where aircraft flights are prohibited. Restricted Areas are not wholly prohibited but may only be entered with authorization from the controlling agency. Other special use areas, such as Military Operations Areas, (MOAs), can be transited without an ATC clearance if operating under VFR or with a clearance if operating under IFR.

Figure 5


ILS/DME 1 RWY 27
RAMSTEIN AB (EDAR)
LANDSTUHL, GERMANY
AL 2231.01 (USAF)
MISSED APPROACH
EMERG SAFE ALT 100 NM 7000
ELEV 782


HI-ILS/DME RWY 27
RAMSTEIN AB (EDAR)
LANDSTUHL, GERMANY
JAL 2231.01 (USAF)
MISSED APPROACH
EMERG SAFE ALT 100 NM
ELEV 782

Terminal requirements are more stringent for both pilots and controllers.

2.1.3 Mission Profile. All tactical military flights are operated under specific mission directives and Instrument Flight Rules (IFR) Flight Plans. The flight plan provides ATC with advance knowledge of flight profiles when under controlled conditions and provides the basis for in-flight information transfer requirements. Missions are, however, subject to change during flight. Such changes affecting a mission in progress will be dictated by the pertinent military mission commander and passed to ATC and the affected aircraft by Command and Control tactical communications networks. Changes in terminal arrival requirements may be dictated by airfield conditions and will be passed by ATC to the aircraft and the military commanders. Within Terminal airspace, ATC becomes the governing authority that issues directives to the inbound pilot to establish the desired sequence and spacing, and advises him of local weather, runway and safety of flight conditions.

With the mission briefed and the flight plan filed, the aircraft will depart the origin airfield and transit to the tactical operating area within controlled airspace. Aircraft will proceed to the directed tactical area, via the assigned route and altitude contained in the flight plan to arrive at a specific geographical point at a prescribed time. Navigation assistance may be provided by third party Tactical Air Control Systems (TACS) if the aircraft is unable to self navigate with the required degree of accuracy, or by a change in mission direction after take off. Today, this assistance relies heavily on active surveillance and voice communications.

Upon changing to tactical mode, aircraft will generally operate under Emission Control (EMCON) conditions which reduce or eliminate the electromagnetic radiation from the aircraft to reduce the probability of detection by enemy forces. Electromagnetic radiation during tactical flight will be limited to safety of flight, mission completion or fire control

requirements. The recommended and maximum durations in the tactical area are specified in the mission briefing.

After completing the tactical portion of their mission, the aircrews will exit the tactical area via the routes specified in their mission briefs. Tactical entry/exit points will vary randomly to deny operational pattern detection and tactical use of that information by enemy forces. This allows ATC and TACS to acquire and track returning tactical aircraft without the need for immediate or voluminous communications. The tactical exit point may not be the same for all aircraft. Each flight or flight unit (leader or wingman) may have a separate exit point dependent on the assigned route to the arrival airfield and the aircraft operational characteristics. This also serves to mask the location of aircraft landing sites. Each mission brief will contain route, altitude and speed information for each aircraft or flight unit from the tactical exit point to the Initial Approach Fix (IAF). Strict adherence to this flight profile will assist ATC and TACS to covertly identify returning friendly aircraft. Figure 6 depicts the major features of a tactical flight profile.

Battle damage or otherwise impaired aircraft may deviate from the preferred return profile in accordance with a specific contingent profile for aircraft returning early, late or in need of priority routing. Mission commanders may vary any of the profile parameters to enhance flight safety and to aid in ATC/TACS identification of returning friendly aircraft. For example, returning aircraft without two way radio communication may be assigned an altitude different from the primary brief, but fly the assigned primary route. Other combinations of altitude, heading changes or time of arrival over specific positions may be used to alert ATC/TACS to changes in aircraft status prior to energizing aircraft communications or data transfer systems.

2.1.4 Operational Decision Considerations. Normal flight operations can be viewed as well defined evolutions during which aircraft perform according to profiles that have been planned,

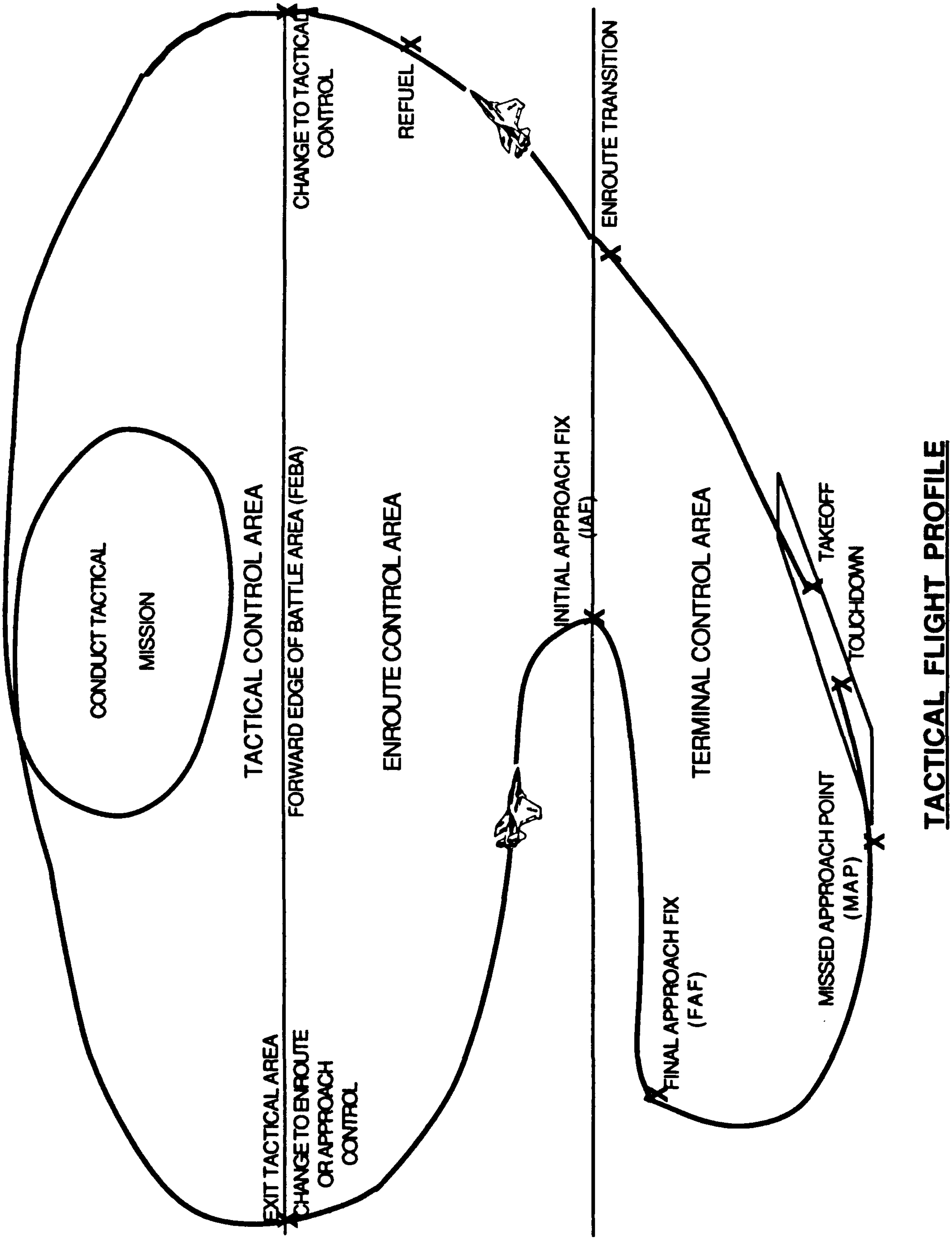

TACTICAL FLIGHT PROFILE
CONDUCT TACTICAL
MISSION
TACTICAL CONTROL AREA
FORWARD EDGE OF BATTLE AREA (FEBA)
ENROUTE CONTROL AREA
TERMINAL CONTROL AREA
CHANGE TO TACTICAL
CONTROL
REFUEL
ENROUTE TRANSITION
INITIAL APPROACH FIX
(IAF)
TAKEOFF
TOUCHDOWN
MISSED APPROACH POINT
(MAP)
FINAL APPROACH FIX
(FAF)
EXIT TACTICAL AREA
CHANGE TO ENROUTE
OR APPROACH
CONTROL

Figure 6

coordinated and briefed. The briefing contains all the information necessary to maneuver the aircraft to the tactical operating area, conduct the tactical mission (including primary and secondary mission alternatives), transit to the landing site (including alternatives) and to land the aircraft. Within this context, aircraft need not communicate with any other activity at any time, from starting engines to shut down, so long as the aircraft performance, weather and tactical requirements remain as briefed.

ACSI focused its analysis on situations requiring significant deviations from briefed operations because they will necessitate new decisions and subsequent communication. These situations will arise in flight and will require either a permanent or temporary change from the briefed profile. Typical profile changes may be dictated by:

a. Failure of aircraft mission essential equipment/battle damage

b. Runway or landing field status degradation

c. ATC equipment failure

d. Weather (making field or route unusable)

e. Tactical mission change

f. Potential aircraft hazard, such as potential collision

Each of these situations requires:

a. Identification of profile change and its stimulus

b. Determination of the immediacy of the change requirement

c. Determination of all options for change

d. Bounding of the options by aircraft capability within the time allowed (immediacy)

e. Interaction analysis to determine the minimum impact to other units (air and ground)

f. Determination and display of resultant choices prioritized by impact

g. Selection of option and provision of direction by the controller

2.1.5 ATALARS Concept of Operation. ATALARS is intended to support and assist the ground controller in performing the above functions. Its primary use will be in a multiple terminal environment, where returning aircraft will be converging on their assigned fields and will be encountering departing aircraft and aircraft that are transiting the area. This is obviously the area of heaviest ATC workload, where a set of powerful decision aids will have the most benefit. Much of the ATALARS logic and many of its algorithms would be useful in tactical aircraft control systems as well, and should be considered for incorporation in those systems.

Fundamental to the operation of ATALARS is the definition of a set of ATC algorithms which will be developed and implemented in the software of the ATALARS Processor. These algorithms will range from the relatively simple, such as the one that will check to see if an aircraft is following the flight plan included in its mission briefing, to the sophisticated, such as the queuing routines to determine who lands when at which airfield. Use of these algorithms will support the development of Artificial Intelligence and Expert Systems approaches to ATALARS.

Artificial Intelligence or Expert Systems use predefined rules to search fixed condition and data statement tables for a match to key words in specific queries. The advantage of AI is that it allows a natural language interface, which permits the operator to input questions in English language syntax. For the non-technical user, this may be easier than using the more common relational Data Base Management Systems (DBMS). The internal operation, however, is similar in theory, and the distinction becomes blurred if the DBMS has a well designed user interface.

The use of AI architecture would allow the maximum flexibility and growth potential. Rules governing which tabular fixed data to access, and under what conditions, would be applied to assist

the ATALARS controller under high tempo conditions and to assure the highest probability of sound decision option development. This would result in an architecture of related databases controlled by AI rule based modules and reduce the work intensity and stress of the ATALARS controller.

The fixed data tables are assigned one to each data category, such as specific aircraft performance characteristics. Taken from the aircraft flight manuals, this data must be quite detailed. For an aircraft it must include, but not necessarily be limited to items such as:

- Type
- Number of crew
- Maximum gross weight
- Maximum landing weight
- Fuel capacity in pounds
- Fuel burn rate at:
  - Full speed (Vmo)
  - Cruise speed
  - Maneuver speed (maximum lift/drag)
  - Holding speed (maximum endurance)
- Aircraft speeds at:
  - Full speed
  - Cruise
  - Maneuver
  - Holding (Approximately 1.5 Vso)
  - Approach (1.3 Vso)
    (Vso = stall speed in landing configuration)
- Jettison stores type
- Jettison stores weight

ACSI was able to develop a functional architecture for the GCU which will meet the ATALARS requirements. There will be four major functions that must be accomplished:

- Man-machine interface
- Message generation
- Data management
- Algorithm processing

The man-machine interface is the controller's workstation. It will consist of a graphic display, a text display, a keyboard and an interactive control device to control cursor movement. Input features may include voice processing. The displays will be capable of showing the status of all elements in the controlled

airspace. This is where all controller interactions with ATALARS will take place, including such items as providing alerts, display and selection of choices for action and system startup/shutdown. Filters will enable the controller to manage his workload by inhibiting the display of irrelevant information. The controller will be capable of directly accessing any of the three other functions.

The message generation function will generate the JTIDS messages needed to control the assigned aircraft. Conversely, message generation will convert received messages into data that can be easily understood by the controller, handled by algorithm processing, and stored in the data base. This function will provide the system's interface to its JTIDS Class 2 terminal.

ATALARS will require the storage and management of large amounts of data. These requirements will be best handled by establishing a separate data management function. This function will handle data that is static, such as aircraft characteristics and approach plate data; and data that is dynamic, or constantly updated, such as aircraft position and status. It will use mass storage devices as well as large amounts of on-line memory.

Finally, there is the algorithm processing function. This is the core of the system and is referred to as the ATALARS Processor elsewhere in this report. Once activated by the controller, the ATALARS Processor will cycle through its algorithms in a defined sequence, moving information to and from the other three functions as required.

Once these functions have been modeled and tested in Phase II, ACSI will be able to make a preliminary estimate of processing and memory requirements for the ATALARS GCU hardware suite. In turn, this information could be used to prepare a hardware architecture for the GCU. A diagram of the proposed GCU functions is shown in figure 7.

As a decision aid to the ground controller, this system may be

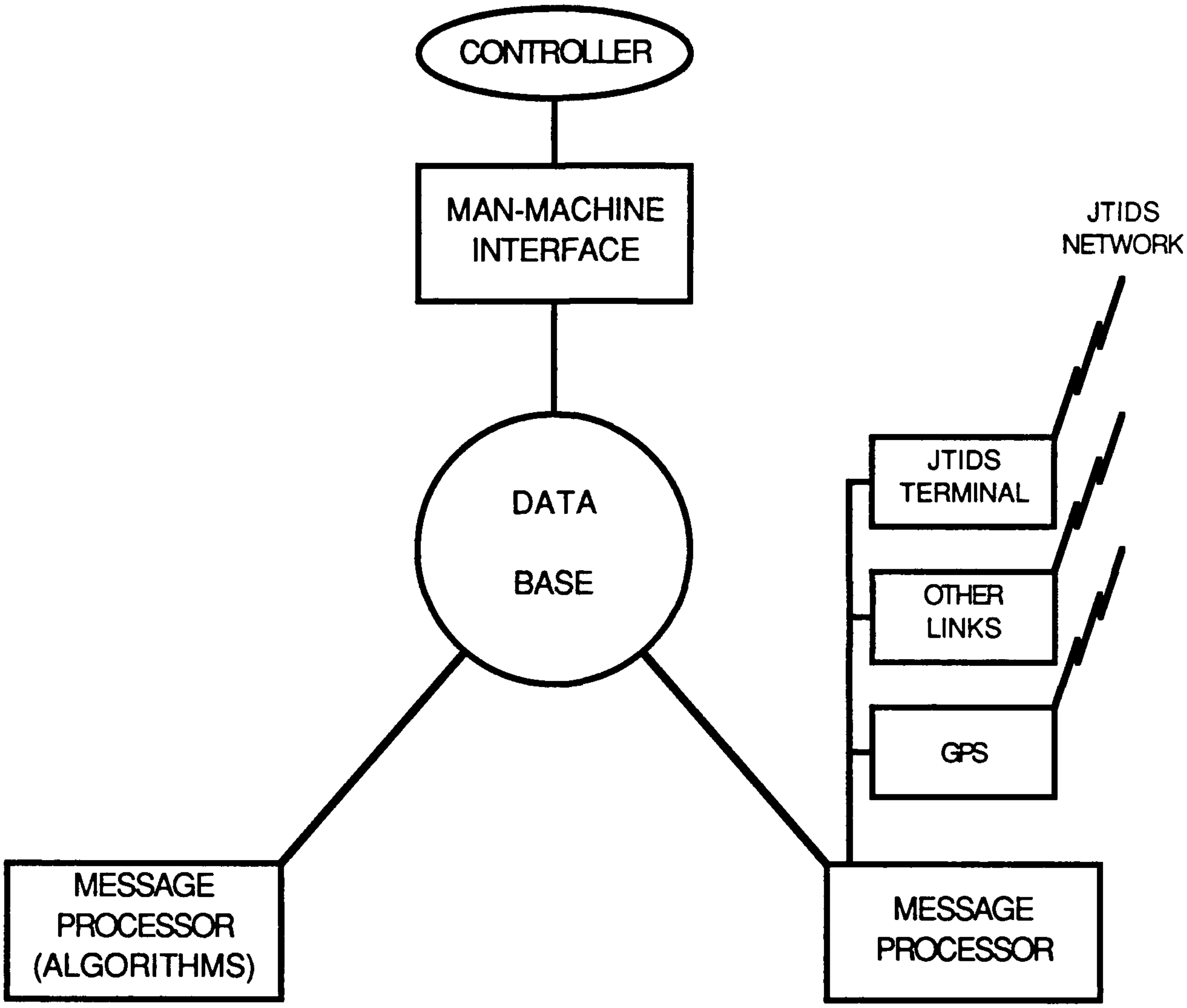


Figure 7

ATALARS FUNCTIONAL DIAGRAM

expanded and refined to handle a wide variety of aircraft control situations while keeping controller workload to a minimum.

There are two modes of operating ATALARS which should be considered, and the software should be designed to allow selection of one mode or the other. In the "manual" mode, the ATALARS processor will present the choices available to the controller to respond to a situation in descending order of priority. When the controller selects one, the appropriate JTIDS message(s) will be constructed and sent. Hence, in a collision avoidance situation, the controller would be shown various options to change the flight parameters of one or more of the involved aircraft. When one of the options is selected, JTIDS messages would be automatically composed and sent to the affected aircraft.

In the "automatic" mode, for selected types of situations or sequences of activities, the ATALARS Processor would select the highest priority alternative, then prepare and transmit the appropriate message(s) subject only to controller override. Although this mode would reduce the controller's workload, it should be used with caution, since it runs the risk of having the controller lose his level of involvement with the overall picture. It would also make the pilots totally dependent on the validity of the software.

The system could also be set up to provide a fail-safe feature when operating in the manual mode. When activated, this feature would watch for controller responses to certain critical alerts, such as a potential collision. If the controller fails to respond within a specified time, the system will switch itself to the automatic mode, select the highest priority option and send the appropriate message(s).

The selection of ATC algorithms for the proof of concept demonstration was a result of analysis of the flight profiles created for the scenario. The algorithms are listed in Table II with short descriptions of each one. In addition, two of them,

TABLE II

ATALARS ALGORITHMS
FOR
PROOF OF CONCEPT DEMONSTRATION

TITLE	FUNCTION	DATA REQUIRED
Course Following	Checks to see if aircraft is on assigned course and speed, warns pilot & controller if off course, recommends recovery.	o Current position heading speed and altitude o Flight plan, including all updates
Safe Separation	Check for inadequate separation between aircraft. Warns pilots and controller, recommends maneuvers.	o Current position, heading, speed and altitude for each aircraft. o Minimum separation distance o Type of aircraft
Collision Avoidance	Checks for potential collisions, warns pilots and controller, recommends evasive maneuvers. Uses Safe Separation algorithm.	o Current position, heading, speed and altitude for each aircraft o Position, heading, speed & altitude for all other controlled aircraft o Terrain and obstructions o Map & other boundaries (FEBA, Minimum Risk, Missile Engagement Zones, etc.) o Aircraft performance characteristics
Approach Plate	Gives pilot instructions for approach & landing	o Position, heading, speed & altitude. o Flight plan, updated o Approach Plate data

TABLE II

ATALARS ALGORITHMS
FOR
PROOF OF CONCEPT DEMONSTRATION - (Cont'd)

TITLE	FUNCTION	DATA REQUIRED
Diversion/ Missed Approach	Gives controller and pilot instructions for alternate approach and landing when originally assigned field will not/can not be used	o Position, heading, speed & altitude. o Approach Plate data for original field. o Flight plan (alternate field assignments) o Airfield data for all other fields in control area (location, status, service capabilities, approach plates, landing/takeoff queue) o Aircraft status (fuel remaining) o Airfield status for original field
Low Fuel	Calculates range available. If insufficient to return to assigned field, alerts pilot & controller. Recommends action to controller. Uses Diversion/Missed Approach algorithm to select alternate fields.	o Aircraft status (fuel, stores, systems, etc.) o Aircraft performance characteristics o Aircraft position, heading, speed & altitude o Flight plan (primary & alternate fields.)

Collision Avoidance and Low Fuel, are discussed in more detail to show more of the considerations that will have to be addressed as the algorithms are more fully developed.

2.1.6 Collision Avoidance Algorithms. Collision avoidance is an area of concern that can be managed with greater simplicity and speed through ATALARS. Using the constant updates to aircraft positions, altitudes, speeds and headings provided to the ATALARS Processor, conditions could be defined which would indicate a potential collision hazard. If those conditions are met, an alert would be provided to both the controller and the aircraft.

In a general sense, aircraft headings, speeds,altitudes and separation distances become the data elements on which the collision avoidance algorithms will operate. The ATALARS processor would constantly project aircraft courses at reported speeds. The resultant estimated positions would be compared first to those of all other aircraft in the controlled airspace and then to the predefined minimum closure or separation rules set as the thresholds for controller alert. Upon attainment of any hazard threshold, the controller would be alerted by a high intensity blinking message on the text display screen such as:

"ALERT - TRACK NO. XXXX, TRACK NO. YYYY COLLISION COURSE"

This would be accompanied by displaying similarly highlighted and blinking markers on the elements involved on the display screen. A similar alert would also be transmitted to the aircraft involved for display to the pilots.

The ATALARS processor would then create a prioritized list of action options available for controller/pilot action. These options would be calculated to avoid a second interference threshold with a third aircraft and to change the aircraft operating parameters to the minimum required to alleviate the situation. This will serve to simplify the controllers' decisions under conditions of stress, when quick response is required for the manual mode described earlier. The highest priority option would feed directly to the message

generation module in the automatic mode.

The following is an example of how the collision avoidance algorithms would function in the manual mode: Two aircraft are operating in airspace where the separation thresholds have been set at two miles horizontal clearance and 1,000 feet vertical clearance. They are on converging courses that will cause them to collide in three minutes at a point 15 miles from their present position. Other flights are at the same altitude to the left of both aircraft flying roughly parallel courses 5 to 7 miles away. The ATALARS processor would give the alerts described above, then calculate the directions available for heading change. Since turning left would cause another conflict, that option would be discarded. The amount of heading change required to maintain a separation of at least two miles would be calculated for each aircraft. The aircraft requiring the least heading change would then be designated as the priority for change. Since no other aircraft are above or below the subject aircraft, climb and descent are both available options. Climbing, however, takes more fuel and may require further adjustments to the flight profile to attain the mission objective at the prescribed times. Therefore, descent is the preferred alternative.

The ATALARS processor would project the alternative flight profiles and compare them to the existing profiles of all other controlled aircraft for maintenance of the stipulated separation rules. This would provide a sifting effect as the system derived a set of alleviating alternatives, which may require the change of more than one flight profile to avert a collision.

The options presented to the ATALARS controller would then appear as:

1. **TRACK # XXXX CHANGE HEADING TO AAA DEGREES**
2. **TRACK # YYYY DESCEND TO BB,BBB FEET**
3. **other options.......**

n. **TRACK # ____, ________________**

By selecting any of the options except the last one, the controller would cause a message to be sent to the designated track number(s) to carry out the change described. The last option would give the controller the opportunity to insert any other command that he chooses, if he disagrees with all of the other options presented. Once the command is inserted, the appropriate message(s) will be sent automatically.

2.1.7 Low Fuel Algorithms. An example of this evolution would be for an aircraft to exit the tactical area with less fuel than was planned. Low fuel status could occur from battle damage (implying other potential flight profile change requirements) or from unforeseen high thrust maneuvers during the tactical phase of the mission such as more weapons delivery passes than planned, evasion or air to air combat.

Flights are normally briefed with both a primary and secondary or emergency recovery field. In today's environment, the response to most low fuel situations would be for the aircraft to divert to the emergency destination without action from ATC or communications between ATC and the affected aircraft.

With ATALARS (JTIDS) equipped aircraft, fuel remaining status is regularly reported to the Ground Control Unit without pilot initiation. The ATALARS processor would derive the fuel consumption rate with each update and check to see that sufficient fuel remains to return to base. The ATALARS processor would also compare the fuel remaining for each controlled aircraft to the low fuel threshold given in the mission briefing, and would alert the ground controller when the fuel remaining on any aircraft reached that level. When the ATALARS controller acknowledged the alert, the ATALARS processor would go through a routine where it would access the primary and secondary recovery fields from the mission briefing, calculate the range available on the remaining fuel at various speeds and altitudes, determine whether the aircraft can reach either of those fields, then determine if there are any other landing sites capable of handling the aircraft within its range. The ATALARS processor

will then display the choices available to the controller in descending order of preference.

In response to the change stimulus of Low Fuel Remaining, the choices would include change(s) to:

- o Altitude
- o Airspeed
- o Route
- o Landing Site
- o External Stores
- o Any combination of the above items
- o Finally, as the last resort in extreme situations: EJECT

Each potential change would be compared to the profiles of other controlled aircraft to determine potential conflicts. If conflicts with other flights result from the selected action, this action would then become a change stimulus to the flight profiles of the affected flights.

Viable changes to the low fuel state aircraft would thus be determined by the ATALARS processor and displayed to the controller based on the capability of the aircraft, the situational immediacy, and the impact on other aircraft or ground stations. When the controller selects one of the choices, the ATALARS processor will access the relevant data files, such as Approach Plates and JTIDS message sets, and construct and transmit the appropriate messages.

This decision process makes use of both table oriented data such as the mission briefing/flight plan, aircraft fuel rates at various speeds, altitudes and weights, and Approach Plate data, as well as calculated data such as the range available based on the fuel remaining at various consumption rates. The table oriented, or fixed, data would be entered into tables for access and extraction by the computational modules which develop the calculated data. Fixed data could be entered either off line by the controller, such as Approach Plate information, or taken automatically from data link messages, such as fuel remaining. The calculated data can then be stored in predefined storage tables for prioritization sorting,

decision rule application and display.

Fuel consumption rates vary with power setting, altitude and aircraft weight. Fuel consumption increases in proportion to aircraft weight at a given speed and in inverse proportion to altitude. Consumption can be calculated when given values of the speed, weight and altitude variables. Since fuel consumption is less sensitive to altitude and weight than it is to speed, altitude and weight can be normalized into gross categories requiring only the input of speed to derive an approximate consumption value. For example, altitude can be split into two categories: above 10,000 feet and below 10,000 feet. Similarly, weight can be categorized for each aircraft type at values based on aircraft empty weight plus two fuel values and two external stores values. These values could be entered into a simplified conditional formula with present aircraft speed to arrive at remaining aircraft flight range. Conversely, the maximum allowable speed to achieve a given range can be derived by providing the desired range and the appropriate weight and altitude values. Since the ATALARS processor will be obtaining fuel remaining, altitude and speed information regularly from the ATALARS equipped aircraft, these values could be used to automatically update the current operating data table from which the processor would calculate range/ endurance.

Aircraft are assigned track identification numbers which are unique to each aircraft in the network. This track number is the reference for specific aircraft communications or operating data. The ATALARS controller can either "hook" the aircraft with an interactive control device, such as a mouse or joy stick, or he may include the track number as reference in keyboard query commands. The AI interface system would support queries such as, "What is endurance?" or, "What is range?" for a "hooked" aircraft. If keyboard entry is preferred, the controller would enter commands such as, "For (track #), what is endurance?" or, "For (track #), what is range?". Geographic data resident in the ATALARS data base could also be accessed to allow automatic determination of landing fields within the range of a specified aircraft. At present, these considerations are addressed by individual pilots and controllers and therefore add

to their workload. Consequently, the results will vary with individual capabilities and the amount of time available to apply to the problem.

2.1.8 Data Requirements. Much of ACSI's analysis focused on the exchange of data between pilot and controller. The data elements were then compared to the requirements for ATC in the ATALARS environment. The analysis covered all aspects of a typical flight, starting with the pre flight briefing then proceeding through the takeoff, enroute, approach and landing segments as well as some common contingencies.

As can be seen from the frequent references to it, the Mission Briefing contains much information that will be essential to efficient operation of ATALARS. Air Force Regulation 60-16, "General Flight Rules," sets the broad requirements for Preflight Planning (Sect. 2-1) and Briefings and Prohibitions (Sect. 2-6). Major commands add their own supplements which are further amplified by pilots in command or formation leaders. The contents of a typical briefing for a Close Air Support (CAS) mission are shown in figure 8. Weather, ceilings, visibility, altimeter, departure instructions (such as heading, fix, climb, intermediate and final altitude) and enroute transition may be briefed minutes before departure. This data would then passed to the Ground Control Unit via command and control networks so that the controller is then prepared to monitor outbound flights and provide direct or redirect advisories if required.

Takeoff in the terminal environment may be conducted without aircraft/ ATC communication. Actual takeoff clearance can be issued by a local controller with light signals from the departure end of the active runway, assuring the departing pilot that all other aircraft are clear of his intended takeoff and departure path. Transition to the Enroute environment occurs at the departure fix, which normally includes an exchange of the data shown in Table III.

The enroute flight environment requires the least amount of flight

FIGURE 8. GENERAL MISSION BRIEFING

Initial Operation Brief (CAS):

- General target information
- Number of squadrons participating
- Flight makeup:
  - Mission leader
  - Order of flights
  - Specific positions (Element leads, wingmen, etc.)

Weather Briefing:

- Home base current weather
- Enroute
- Over target
- At tanker
- On return

Intelligence Briefing:

- Overall intell assessment of situation in battle area
- Stateside observations
- Specific target information
  - Target make up (number, type, etc.)
  - Type of construction
  - Precise location
  - Vulnerability
  - Defenses:
    - Enroute
    - At target
- Forward edge of battle area (FEBA)
- Forward line of own troops (FLOT)
- Safe areas:
  - Actions to take
  - Safest part of area
  - Points of contact
  - Who/how to contact

FIGURE 8. GENERAL MISSION BRIEFING - (Cont'd)

Day/night actions
Use of pointee/talkees, chits, gold pieces

Personal Equipment Briefing:
- Ejection sequence/procedures
- Maneuvering chute
- Locator beacon
- Use of survival radio
- Issue guns/ammo
- Use of various other survival items

Weapons/Ordnance Briefing:
- Type of ordnance loaded
- Destruction capacity
- Minimum altitude for release
- Specifics on load
- Arming/dearming procedures
- Cautionary items

Operations Briefing -(Specific)
- Start engine time/UHF frequency
- Marshalling " / " "
- Ordnance check/procedures
- Take off time/sequence/frequency
- Tanker location (anchor)/procedures/frequencies
  - Time on
  - Fuel offload
  - Time off
- Route & target:
  - Outbound control/frequencies
  - IFF/SIF Mode & Code
  - Ingress to target/heading/altitude
  - Controller in target area/frequencies
  - Time on target
  - Tactics/weather dependent
  - Maximum stay time on target

FIGURE 8. GENERAL MISSION BRIEFING - (Cont'd)

Egress from area/heading/altitude
IFF/SIF Mode & Code
Use of minimum risk corridor
Altitude/Code outside MRC

Recovery procedures:

Controller/frequency
Type of Approach
Diversion:
Primary alternate
Secondary "
Hung ordnace procedures
Communications out procedures
Switchology

TABLE III. ENROUTE DATA ELEMENTS

AIRCRAFT		GROUND	
SEND	REQUEST	SEND	REQUEST
ID	WEATHER	ACKNOWLEDGMENT	FUEL
POSITION	ALTIMETER	COURSE	STATUS
ALTITUDE	CHANGE TO:	ALTITUDE	
TRUE AIR SPEED	ROUTE	TRUE AIR SPEED	
ACKNOWLEDGMENT	ALTITUDE	ALTIMETER	
STATUS		MIN RISK CORRIDOR	
FUEL		MISSILE ENGAGEMENT ZONE	
WEAPONS		FEBA	
SYSTEMS		WEATHER	
DAMAGE			

or advisory data to be transferred between the pilot and the ground controller. The data generated or requested by both the aircraft and the controller is the same as that initially exchanged upon transition to the enroute environment.

The terminal environment requires much more information to be exchanged. For normal operations with fully capable aircraft and crew, this can be handled by a standard set of data which may also be transferred by standard message format. In addition, the data exchange rate will increase with increasing proximity to the runway. Landing and takeoff both occur in the Terminal environment and include operations from the runway to a transition fix at a designated altitude. Table IV depicts the data elements generated or requested by both the aircraft and ATC in the Terminal Approach and Landing environment.

Mission briefing material will include mission abort instructions which contain the same types of data as the approach information requirements. The abort or divert approach data is provided for those cases where there is aircraft status reduction in power plant, navigation or weapons systems and it cannot reach its assigned recovery field.

Pilots may, at any time, request updates to any information normally provided by the ATC system.

2.2 Data Set Communication Requirements

2.2.1 JTIDS Description. In all of the efforts to refine the ATALARS concept and plan for an early proof of concept demonstration in Phase II, it has been assumed that the ATALARS automatic data link is to be implemented using the Joint Tactical Information Distribution System (JTIDS).

JTIDS is a Time Division Multiple Access (TDMA) communications system operating in the L-Band frequency range. It provides jam resistant digital communication of data and voice for command and control, navigation, relative positioning and identification. Its

TABLE IV. APPROACH & LANDING DATA ELEMENTS

AIRCRAFT		GROUND	
SEND	REQUEST	SEND	REQUEST
ACKNOWLEDGMENT	ALTERNATE ROUTE	IAP:	FUEL
FUEL	WEATHER UPDATE	POSITION	STATUS
STATUS		ALTITUDE	TYPE LANDING
		TIME	
		TYPE LANDING	
		TDZ POSITION	
		RUNWAY HEADING	
		HOLDING INSTRUCTIONS:	
		POSITION	
		DIRECTION	
		LEG LENGTH	
		STD/NON-STD	
		EAC TIME	
		IAF:	
		POSIT	
		ALTITUDE	
		COURSE	
		GLIDE SLOPE	
		FAF:	
		POSITION	
		ALTITUDE	
		DH	
		TDZ ELEVATION	
		CEILING	
		VISIBILITY	
		WIND	
		ALTIMETER	
		MISSED APPROACH:	
		COURSE	
		ALTITUDE	
		WEATHER	

operating range is greater than 300 nautical miles (nominally) in line-of-sight, with an extended range option of 500 nautical miles. JTIDS communications operate on the principle of time sharing the same randomly hopping frequencies as other subscribers within the communications net. To accomplish this, a time cycle (or epoch) is established in which time slots are repeated every 12.8 minutes. The epoch is divided into 98,384 individual time slots of 7.8125 milliseconds each, thus providing 128 time slots per second for the transmission or reception of data.

Each subscriber is assigned specific time slots for transmission and reception based on the particular message requirements necessary to support its mission. A subscriber may have many transmit time slot assignments, consecutive or spaced, within the epoch. Additionally, a subscriber may share any of the 128 nets that JTIDS is capable of supporting, depending on how the subscriber's terminal is programmed. Each net functions in the same time reference and line-of-sight area but with a different frequency scheme. While typically only one subscriber will be designated as being able to transmit in a specified time slot, many subscribers may be designated to receive on a specific net in a specific slot. Thus JTIDS permits subscribers to track each other and permits them to select the information they need from the interoperating nets to "see" what the other subscribers "see" in both the surface and air environments.

Within JTIDS, one subscriber is designated to serve as the time reference, synchronizing all the other subscribers to the same timing throughout the interoperating nets. With each subscriber accurately synchronized to a common system time, and with a signal structure that permits accurate signal Time-Of-Arrival (TOA) measurements, JTIDS can also provide a relative navigation and position location capability with other JTIDS subscribers.

Also included within the JTIDS concept is a document called the Technical Interface Design Plan (TIDP). The TIDP defines, in detail, the set of messages and their content which will be used in the exchange of digital information on a JTIDS communication

net. Since the JTIDS TIDP is a classified document, all references to JTIDS messages in this report will be generic.

2.2.2 Comparison of JTIDS and ATALARS Requirements. JTIDS is recommended as the ATALARS data link for several reasons. First, it can handle and effectively present the data and messages needed for ATC. Next, through its relative navigation and PPLI reporting capabilities, JTIDS can provide the desired indirect surveillance of controlled aircraft to the ground controller. JTIDS also provides the secure transmission and jam resistance needed for ATC in the tactical environment. Finally, JTIDS is subject to the standards for tactical C3 interoperability, so ATALARS will employ systems already being developed for application on a wide variety of aircraft and ground installations. JTIDS will allow ATALARS to interface with the Air Defense Tactical Systems.

The capabilities of JTIDS were compared to the requirements for the ATALARS proof of concept demonstration, first to determine the feasibility of using JTIDS as the ATALARS data link and second, given the feasibility, to determine the scope of any necessary changes. Analysis of the TIDP revealed that all the parameters required to support the Approach Control aspects of ATALARS are contained within the JTIDS message sets. The analysis did indicate, however, that some of the required information, although contained in the TIDP, was fragmented and was not conducive to efficient operation of an ATALARS system. In these cases several messages would have to be transmitted to convey the required information where, with some judicious modifications, a single message might suffice. At first it seemed reasonable to redefine portions of the TIDP or specify new messages custom tailored to support the efficient operation of the ATALARS concept. After careful consideration, however, this idea was dropped because it would eliminate completely any possibility of demonstrating the ATALARS concept with live elements that are currently JTIDS capable. By not modifying the TIDP, a live demonstration of the ATALARS concept might be possible using F-15's which have been equipped with a JTIDS

capability. Although the government currently has no plans for such a live demonstration, one could be accomplished if desired, which would not be the case if the TIDP were modified. In addition, several messages that would support ATALARS were found in the predecessor to the JTIDS TIDP, known as the Interim JTIDS Message Set (IJMS). Some of these messages can be handled by the F-15's JTIDS terminal and some cannot. The EJSE will be able to handle most of the messages when the upgrades now in process for the Modular Control Equipment (MCE) program are complete. Subsequent analysis indicated that the inefficiencies of the TIDP relative to ATALARS can be tolerated, provided that no high capacity scenarios are attempted.

Although there are no current plans by the Air Force to implement it, the JTIDS TIDP includes a message that can assign multiple way points which could be used for approaches or for flight plans. It also includes a message that could provide close control up to a point 10 seconds before touchdown and also includes the capability to tie into the aircraft's auto pilot and fly the aircraft in a manner similar to flying a Remotely Piloted Vehicle. Use of messages such as these would add significantly to the capabilities of ATALARS.

To determine which messages could be used in the ATALARS application, the various types of data needed in the different environments were analyzed for common elements and those common elements were compared to the contents of the messages. The common elements of data are shown in Table V. Descriptions of IJMS/TADIL-J messages that could be used with ATALARS are listed with the platforms in which they are implemented in Table VI.

2.3 EJSE Utilization for the Proof of Concept Demonstration

2.3.1 EJSE Description. Analysis during this study has shown that JTIDS provides both the indirect surveillance and the automatic data link capabilities required by ATALARS. Consequently, the Enhanced JTIDS System Exerciser, which was developed by ACSI to support the verification and

TABLE V

ATALARS INFORMATION EXCHANGE

PILOT TO CONTROL	TADIL-J/IJMS MESSAGES		CONTROL TO PILOT
	GROUND PHASE		
Identification, Position	*Air		
	PPLI		
Request for taxi, takeoff	C4-3		
instructions			
		**V1-1	Taxi instructions
			RW in use, etc.
Acknowledgments (through			
operator ack selection			Ceiling, visibility,
in cockpit)		I1-1	altimeter setting,
			wind, (direction,
			speed)
		**C1-11	Clearance to taxi/
			change to departure
			frequency
	ENROUTE PHASE		
ID, position, alt, etc.	*Air		
	PPLI	**C1-11	Changeover instructions
			to enroute controller
Operational status	*Plat-		
	form		
	Status		
Request weather update	**Data		
	Update	I1-11	Transmit weather update

[ATALARS.TX/317C]

TABLE V

ATALARS
INFORMATION EXCHANGE - (Cont'd)

PILOT TO CONTROL	TADIL-J/IJMS MESSAGES		CONTROL TO PILOT
	Request	I1-3	Transmit upper air data
		I1-4	
		I1-5	Transmit severe weather data
Location of hostile air/ground units		*Air Track	Hostile information from ATALARS, AWACS, CRC, etc.
		*Mission Asgnmt	Repositioning of Minimum Risk Corridor, FEBA, etc.
		*Vector	Change of altitude/heading/speed for traffic control

TARGET AREA PHASE

PILOT TO CONTROL	TADIL-J/IJMS MESSAGES		CONTROL TO PILOT
		**Reference Pt	Hazard information
ID, alt, position	* Air PPLI		
Operational status	*Platform Status		
		**C1-11	Handover to target area control

TABLE V

ATALARS
INFORMATION EXCHANGE - (Cont'd)

PILOT TO CONTROL	TADIL-J/IJMS MESSAGES		CONTROL TO PILOT
	RETURN TO BASE PHASE		
Request for WX update	C4-3	I1-1 thru I1-5	Weather observation, severe WX, ceiling, visibility, altimeter, etc.
Request for airfield status	C4-3	Airfield Status	Critical information transmitted
Landing information		** V1-1	Runway in use, altitude, airspeed, heading, etc.
Operation data	*Platform Status	** V1-1	Missed approach/diversion information

*Messages currently processed by EJSE
**Messages to be processed in MCE upgrade to EJSE

Other messages will require approval and expansion for applicability to ATALARS..

TABLE VI. IJMS/TADIL-J MESSAGES FOR ATALARS

	MESSAGE TYPE	PLATFORM (1) EJSE (2)	E-3	MCE	F-15
1. Air PPLI (Precise Participant Location & Identification)	TADIL-J	X	X	X	X
2. Air Platform Status	TADIL-J	X	X	X	X
3. Air Track	TADIL-J	X	X	X	X
4. Aircraft Control Message	IJMS	X		X	
5. Aircraft Vectoring and Close Control Message	IJMS	X		X	
6. Area Severe Weather Report	IJMS				
7. Airfield Status	TADIL-J				
8. Controlling Unit Change	TADIL-J	X	X	X	X
9. Flight Path	TADIL-J				
10. Handover	TADIL-J	X	X	X	
11. Interrogation Message (to request weather info, etc.)	IJMS	X		X	
12. Land (Ground) Point	TADIL-J	X	X	X	X
13. Mission Assignment	TADIL-J	X	X	X	X

TABLE VI. IJMS/TADIL-J MESSAGES FOR ATALARS - (Cont'd)

		PLATFORM (1)			
	MESSAGE TYPE	EJSE (2)	E-3	MCE	F-15
14. Moving Severe Weather Report	IJMS				
15. Pairing	TADIL-J	X	X	X	
16. Pairing Association MSG. for Tracks & Special Points	IJMS	X		X	
17. Precision Aircraft Direction	TADIL-J				
18. Target/Track Correlation	TADIL-J				
19. Upper Air Data Report	IJMS				
20. Vector	TADIL-J	X	X	X	X
21. Weather Observation	IJMS				

Note: (1) This is a list of messages of use to ATALARS, and is not necessarily a complete listing of messages processed by the EJSE, E-3, MCE or F-15.

(2) EJSE Messages include those being implemented for the MCE Program, which will be available by August, 1988.

demonstration of the JTIDS concept is the logical candidate for the proof of concept demonstration. The EJSE is capable of exercising, monitoring and participating in a JTIDS TDMA network. It is a self-contained, user friendly system that is capable of simulating JTIDS elements while collecting and displaying all the various parameters by which the JTIDS network operations are monitored.

The EJSE consists of a Terminal Group (TG), a Simulation Group (SG) and a Display Group (DG), all of which are interconnected via a Local Area Network (LAN). The system is diagrammed in figure 9. For application of the EJSE for the ATALARS proof of concept demonstration, only the Simulation Group and the Display Group will be used. The Terminal Group would be used only if the government elected to conduct a live demonstration.

Currently the Simulation Group provides both off-line and on-line functions for the EJSE. Off-line, the Simulation Group is used to create event driven scenarios from user supplied event data which can be stored on tape or disk. These event data are geographic locations and/or times depending on the requirements of the scenario and the element type being simulated. An element type is either a participating unit (JTIDS equipped) reporting its own position and status, or a track whose location is being reported by a participating unit. The Simulation Group creates a data base containing element report message data and positions used in extrapolation of simulated tracks. A position report or track message is then created for each element at the recurrence rate specified by the user. These element report messages, with extrapolated position data, are then written to magnetic storage media with any additional command and control messages interleaved at their appropriate times. The result is a time ordered scenario tape or disk file containing all the JTIDS messages required to simulate the desired tactical environment. On-line, the Simulation Group processes messages from a Scenario file for transmission to the Terminal Group and Display Group via the LAN.

The Display Group creates a tactical situation display on the basis

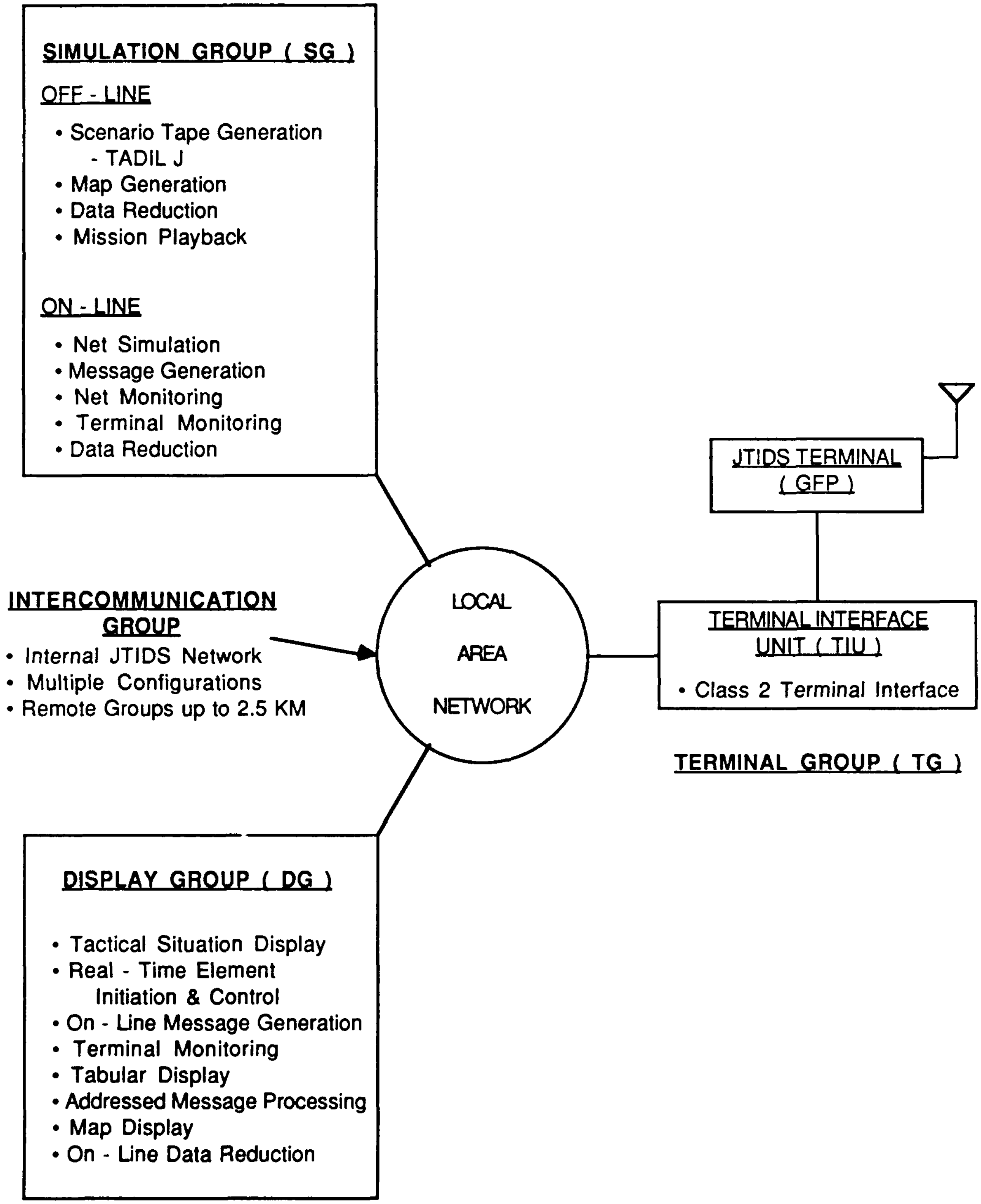


Figure 9

EJSE SYSTEM CONFIGURATION

of element reports received via the LAN. This situation display depicts the type, heading and speed of elements reporting or being reported on the JTIDS network. This display also provides controller selectable options for displaying both simulated and real network data in real time, and can provide filtering by element in either environment. These elements are selected for display based on their range from the display center and on a specified prioritized element type filter list. Each element's position on the display screen is scaled relative to its reported position and to the operator's specification of display center and range. In addition, an operator may request the display of data blocks with optional filtering to show as little or as much information as desired for any or all of the displayed elements.

2.3.2 EJSE Modifications Required. To support an ATALARS proof of concept demonstration in Phase II, some modifications will be made to the EJSE which will enhance the system's current capabilities. The Display Group will be modified so as to function as an ATALARS Ground Control Unit rather than as a network monitor and the Simulation Group will be modified to provide a real-time interactive simulation capability.

Added to the Display Group's current capabilities will be the capability to assess the current situation and, on the basis of that assessment, to automatically generate and transmit JTIDS messages. This control capability will be provided through the implementation of the ATALARS algorithms discussed earlier and developed during Phase I and in Phase II. The Display Group will maintain a data base containing the key information (as defined by the algorithms) for each element in a given scenario. This information will be initialized at the beginning of the scenario and will be updated from information gleaned from the JTIDS messages transmitted by the individual elements over the course of the scenario. At regular intervals, the Display Group will execute iteratively through the ATALARS algorithms to determine if any of the elements must be vectored to a new heading, speed, altitude or position. For those elements which must be vectored as described above, the Display Group will present the operator

with the action required, or offer recommended choices, if appropriate. When the operator affirms the action required, or selects one of the choices, the Display Group will format the appropriate legitimate JTIDS message and transmit it over the LAN.

In addition to determining, formatting and transmitting these position related JTIDS messages, the Display Group, in its role as Ground Control Unit will also transmit net management type messages to the scenario elements. These net management messages will allow participating elements to report their position and status at increasing frequency as they get closer to landing. When fully developed, it is anticipated that the ATALARS Ground Control Unit will be assigned its own JTIDS net, due to the large number of slots it will require. The Ground Control Unit will then distribute its time slots to elements under its control based upon the current situation, both overall and specific to the element receiving the slots.

In order for the Simulation Group to support an ATALARS demonstration, its simulation capability must be made to run in real-time and be interactive with command messages received from the Display Group over the LAN. Converting the Simulation Group's scenario generation capability to run in real time will require some restructuring of the program, but not a significant restructuring, because most of the program is already set up for real-time operations. What is necessary is to have the system create its element data base in memory rather than on disk and have the element reports output to the Display Group via the LAN rather than to magnetic tape.

The more difficult task for the Simulation Group will be to make the simulation interactive. The Simulation Group must be made to respond to the vectoring and net management messages formulated and transmitted by the Display Group. Even these changes would be straightforward if the positional changes were made to be instantaneous. With instantaneous changes, it would almost be as simple as inserting the new number into the Simulation Group's

data base. The problem with that is that aircraft don't make instantaneous changes in speed, heading, altitude,and other flight parameters. Consequently, instantaneous changes would produce an adverse effect on the ATALARS algorithms as they are both time and value sensitive. Timing of messages is as important as their content, so the responses programmed into the Simulation Group will have to closely emulate the characteristics of the simulated aircraft. Figure 10 depicts the architecture of the EJSE as modified for the ATALARS proof of concept demonstration.

A scenario for the ATALARS demonstration would be initially set up with a number of elements each flying in a specified direction and each having a specified start time and reporting recurrence rate. Each element would have a mission briefing on file in the Display Group. The Simulation Group would start creating position reports on the basis of this information. These position reports would be transmitted to the Display Group in the form of JTIDS PPLI messages. The Display Group would process the messages received such that the Ground Control Unit data base would be updated. Using this data base information as well as the airfield status information and the aircraft flight characteristics built into the system as inputs, the Display Group would cycle through its ATALARS algorithms generating vectoring and net management commands which it would transmit over the LAN to the Simulation Group. These messages would adhere to the protocols of the JTIDS TIDP. The Simulation Group, upon receipt of these messages, would modify the trajectory or reporting rate of the appropriate element using data base maintained flight characteristics such as turn radius, rate of altitude change, or rate of speed change. This process would then continue until all elements were on the ground or the scenario was terminated.

2.4 Scenario

2.4.1 Introduction. One of the products of this study was to be a demonstration of what the Phase II demonstration on the EJSE

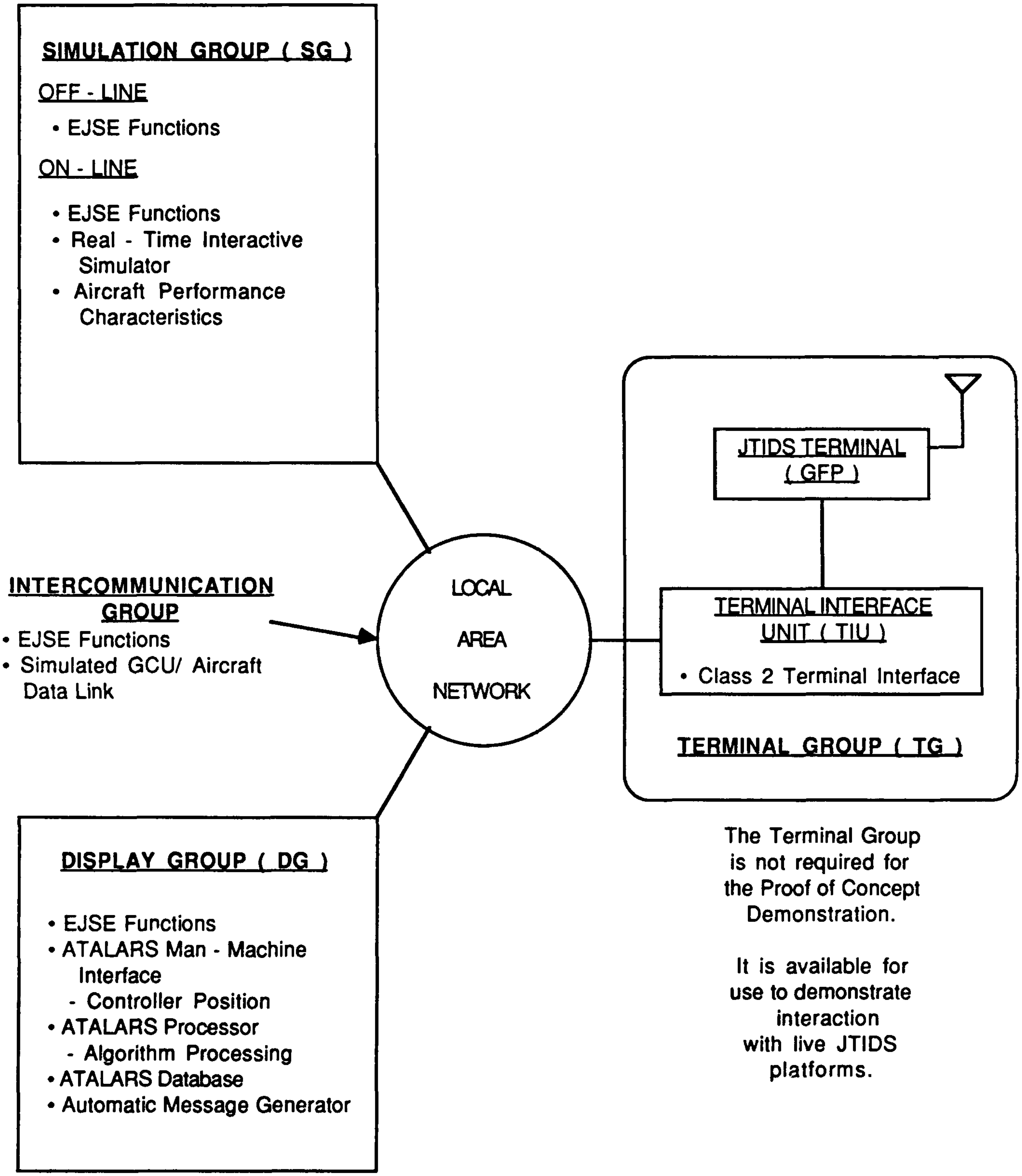


Figure 10

ATALARS DEMONSTRATION SYSTEM CONFIGURATION

will look like. It would show the tracks of aircraft under simulated ATALARS control complete with relevant message traffic. The items that would be missing would be functioning algorithms in the Display Group and functioning responses in the Simulation Group. Even without these features, some of the potential attributes of ATALARS, such as the elimination of voice communication and direct surveillance, can easily be seen. These features make the ATALARS demonstration on the EJSE different from other ATC simulators.

The functions shown in this scenario are relatively simple and involve a limited number of aircraft. This was done so that the viewer could concentrate on the ATALARS interaction with an aircraft and not be distracted by a high volume of activity. In addition, since the algorithms will be relatively expensive to develop and implement, only a small number of them will be necessary at the outset to start the proof of concept in Phase II. The condensed script for the scenario can be found in Table VII. It will be a useful reference for anyone who views the demonstration.

2.4.2 Scenario Description. The scenario that has been developed for Phase I is to be situated in the 4th Allied Tactical Air Force area of West Germany, since ATALARS is initially intended for use in a tactical situation. There are ten airfields shown (Baumholder, Bitberg, Buchel, Frankfurt, Hahn, Hanau, Ramstein, Sembach, Spangdahlem and Weisbaden) each with different runway lengths and aircraft service capabilities. There are 21 aircraft in the scenario, 17 of which are friendly and four are East German hostiles. No tactical interaction with the hostiles will take place, however.

Of the friendly aircraft, 16 are ATALARS (JTIDS) equipped and one represents transient friendly traffic which is not ATALARS equipped. The ATALARS equipped aircraft consist of one AWACS E3A, six transient aircraft and a mix of returning F15's and F16's, which, for the purpose of this scenario, have differing airfield requirements such that all aircraft cannot land at all airfields.

TABLE VII

SCRIPT FOR ATALARS SCENARIO

SCENARIO NUMBER 5
CARD IMAGE TAPE 1020
TAPE GENERATION 135
NUMBER OF ELEMENTS - 21
DATE - 13 JANUARY 1988

ASSUMPTIONS:

* ALL AIRCRAFT AND CONTROLLING AGENCIES (ATALARS, AWACS,CRC, ETC.) HAVE BEEN PREBRIEFED ON RECOVERY BASES FOR MISSION AIRCRAFT. THIS MINIMIZES NEED FOR VHR/UHF/JTIDS VOICE TRANSMISSIONS.

* AIRCRAFT UNDER ATALARS CONTROL ARE JTIDS EQUIPPED.

* BASIC JTIDS INFORMATION EXCHANGE IS CONSIDERED ADEQUATE FOR NORMAL CONTROL. JTIDS VOICE WOULD BE AVAILABLE FOR SUPPLEMENTAL DATA (NECESSARY FOR INFLIGHT EMERGENCIES, BATTLE DAMAGE, ETC.).

* PLAYERS:
  TNSC'S 4001, 4002, 4201, 4202, 4203, 4204, CROSSING TRAFFIC.
  TNSC'S 3601,3602, 2202, (F-15'S RECOVERING AT BITBURG AB)
  TNSC'S 5001,5002, 2201, (F-16'S RECOVERING AT HAHN AB)
  TNSC'S 7604,7606, 2203, (F-15'S RECOVERING AT RAMSTEIN AB)
  TNSC 2001, AWACS IN ORBIT
  TNSC' 6001, 6002, 6003, 6004, EAST GERMAN HOSTILES
  TNSC 2100, FRIENDLY BEING REPORTED BY AWACS, NOT UNDER ATALARS CONTROL

* MAP DEPICTS:
  WEST GERMANY
  PRIMARY AREA OF INTEREST IS 4TH ALLIED TACTICAL AIR FORCE AREA
  MISSILE ENGAGEMENT ZONE
  MINIMUM RISK CORRIDOR
  FEBA IS CONSIDERED TO BE THE EAST GERMAN/CZECH BORDER
  SEMBACH AB (TACC LOCATED AT THIS SITE)
  BITBURG AB (36 TFW - F-15'S)
  HAHN AB (50 TFW - F-16'S)
  RAMSTEIN AB (F-15'S, F-16'S AND COMBAT SUPPORT BASE)
  FRANKFURT AB (FORWARD RECOVERY BASE FOR BATTLE DAMAGE)
  SPANGDAHLEM AG (RUNWAY ONLY - NO SERVICES)
  WEISBADEN AB (AWACS BASE)
  BUCHEL AB (TURN AROUND CAPABILITY ONLY - FUEL/OXYGEN)
  HANAU AB (CRC LOCATED AT THIS SITE)
  BAUMHOLDER AB (USED AS RECOVERY CAP POINT)

TABLE VII (Cont'd)

ATALARS CONTROL - CENTERED IN 4TH ATAF AREA

000001 - SCENARIO BEGINS WITH CROSSING TRAFFIC ACTIVE IN THE ATALARS CONTROL AREA. AWACS IS ON STATION AND STARTS ORBIT.

000100 - SEVERAL FRIENDLY AND HOSTILE FIGHTERS APPEAR ENROUTE TO RECOVERY BASES.

000130 - 4201/4202 ON COLLISION COURSE AT 32000 FEET.

000156 - ATALARS DIRECTS 4201 TO DESCEND TO 26000 FEET USING VECTOR MESSAGE.

000201 - 4201 BEGINS DESCENT.

000255 - 4201 REACHES 26000.

000315 - RETURNING FRIENDLY/HOSTILE FIGHTERS CONTINUE TO APPEAR.

000354 - HANDOFF OF 2203 BY AWACS TO ATALARS USING "CONTROLLING UNIT CHANGE" MESSAGE OR IJMS "C1-11 -AIRCRAFT CONTROL" MESSAGE.

000400 - 2203 CHANGES ACTIVITY FROM CLOSE AIR SUPPORT TO RETURN TO BASE.

000406 - ATALARS DIRECTS 4203 TO CHANGE HEADING TO 180 TO AVOID COLLISION WITH 4204 USING "VECTOR" MESSAGE.

000412 - 4203 CHANGES HEADING TO 180.

000747 - ATALARS DIRECTS 2203 TO DESCEND TO 20000 AT 400 KTS WHILE VECTORING TO WEISBADEN.

000754 - 2203 BEGINS DESCENT TO 20000.

001317 - ATALARS DIRECTS 2203 TO DESCEND TO 3000 FEET AT 220 KTS VECTOR TOWARD BAUMHOLDER.

001318 - 2203 BEGINS DESCENT TO 3000.

001658 - ATALARS DIRECTS 2201 TO HEADING OF 180 AT 2600 FEET. (VECTOR MESSAGE). VICINITY OF HAHN AB.

001706 - ATALARS VECTORS 2203 TO BASE LEG SOUTH OF BAUMHOLDER.

001830 - ATALARS RECEIVES "AIRFIELD STATUS" MESSAGE FROM HAHN INDICATING FIELD IS CLOSED.

001914 - ATALARS DIVERTS 2201 TO BUCHEL AB AT 2600 FEET.

002130 - ATALARS CLEARS 2201 TO LAND AT BUCHEL USING EXPANDED IJMS

TABLE VII (Cont'd)

V1-1 MESSAGE.

002331 - 2201 LANDS AT BUCHEL.

002400 - ATALARS CLEARS 2203 TO LAND AT RAMSTEIN AB USING V1-1 MESSAGE.

002505 - 2203 LANDS AT RAMSTEIN.

003000 - ALL TRANSMISSIONS CEASE. END OF SCENARIO....

The scenario begins by showing two collision avoidance situations. These simulate situations where ATALARS notes that two aircraft are on converging courses and recommends the directions to be given by the controller to prevent their colliding. The messages are transmitted to the aircraft using the JTIDS data link. It should be noted that the information on the position of the aircraft was net), and that no voice communication was required.

The returning aircraft (the F15's and F16's) enter the area controlled by the Ground Control Unit through a minimum risk corridor, and begin to proceed to their bases. For clarity, this scenario will focus primarily on one aircraft as it returns to Ramstein.

AWACS hands off the aircraft to ATALARS with a JTIDS "Controlling Unit Change", or IJMS "Aircraft Control" message. (Note: these two messages are not presently processed by the EJSE, but they will be implemented for the MCE program.) ATALARS then gives the aircraft a series of vector messages that provide the landing approach to Ramstein. It is envisioned that the ATALARS data base will contain, in tabular form, the information found on the Approach Plates for all airfields in its control area. When the flight plan for a particular aircraft is accessed by ATALARS, it will show the primary and alternate fields assigned. Then, when ATALARS has taken control and the aircraft changes its activity designation to "return to base", the appropriate Approach Plate data will be called up and used to vector the aircraft to its assigned field. The pilot's acknowledgment of the vectoring messages will be the initial feedback on the plane's activity. The plane's position would then be tracked automatically to assure that it is following the approach instructions, and ATALARS will provide a warning to the controller if the aircraft strays too far from its assigned path. When fully developed, ATALARS will be going through these steps for all of its controlled aircraft. Therefore, the Ground Control Unit, upon receipt of each plane's return to base message, will analyze its request to land with respect to all previously received requests and will assign the aircraft to the appropriate place in the landing queue for the selected airfield. A further iteration of this

process will occur if emergency conditions are reported by one or more aircraft, such as low fuel, live ordnance on board or battle damage. Then ATALARS would recommend the best solutions to the problem presented by the aircraft and, at the same time, try to minimize the impact on all the other aircraft under its control so that they are not all forced to change their approach plans and timing.

The Ground Control Unit will continue to cycle through its internal ATALARS algorithms providing finer and finer control of the aircraft until the aircraft are finally on the ground. As each aircraft gets closer to its assigned airfield, the communications between it and the Ground Control Unit will become more frequent, thus providing tighter feedback control. This preliminary scenario leaves the message recurrence rate at a constant six seconds, but varying rates will be used in the more sophisticated simulations that will be developed in Phase II. This scenario also assumes that the landings will be under Visual Meteorological Conditions (VMC). Under more adverse conditions, ATALARS will have to rely on something more accurate than JTIDS alone as a precision landing aid from the time the aircraft reaches Decision Height until it touches down. Capabilities would include such items as an interface between JTIDS and GPS or a portable MLS with limited range and capable of being easily turned off when not in use.

The final activity shown in the scenario is a diversion of a plane intending to land at Hahn when the Ground Control Unit receives an "airfield status" message indicating that Hahn is temporarily unavailable. The aircraft is vectored to Buchel, about 20 miles away, at low altitude, and is cleared to land with an IJMS "aircraft vectoring and close control" message. When the simulation is more fully developed in Phase II, the operator/observer will be permitted to alter the status of one or more of the airfields in real time just as if the Ground Control Unit had received notification that the airfield had been destroyed by enemy fire. As a result of this status change, the system would have to "instantaneously" re-evaluate the total situation, and then re-assign and re-vector all affected aircraft based on the new set of conditions. Here again, the special requirements presented by the aircraft would have to be

considered while at the same time trying to minimize the overall impact on all the aircraft under the Ground Control Unit's control.

This scenario, which is a simulation of the proof of concept demonstration, is available now for viewing. It demonstrates both graphically and on the basis of message traffic what the Phase II simulation will accomplish when the Simulation Group is set up to interactively simulate a number of aircraft and the Display Group is set up to simulate the ATALARS Ground Control Unit.

3.0 PROPOSED EFFORTS FOR PHASE II

3.1 Introduction

The overall goal of ACSI's Phase II effort is to produce a proof of concept demonstration for the GCU portions of ATALARS. The preceding sections have provided the background and described the activities that would be required to accomplish that objective. In this section, ACSI will define the specific activities required and their sequence of accomplishment. This section will conclude with a description of optional features and enhancements which could be added as development of the concept progresses.

3.2 Develop / Conduct Demonstrations

ACSI will use the EJSE as the vehicle for the ATALARS Proof of Concept demonstration, and will start with the scenario developed for Phase I. The system for the demonstration will be developed incrementally, as illustrated in figure 11. As significant portions of work are complete, the added capabilities will be demonstrated. The final demonstration in this sequence would serve as an ATALARS Proof of Concept demonstration. When the proposed modifications are complete, the EJSE Display Group will have become a model for the ATC function of the ATALARS Ground Control Unit.

3.3 Display Group Modifications

3.3.1 Install Algorithms. The principal task for Phase II is to install in the EJSE Display Group the algorithms described in Section 2.1. They represent the first increment of the comprehensive set of ATC algorithms that would eventually reside in the ATALARS processor. In addition to the algorithms themselves, the design would include rules for their sequencing and frequency of processing as well as how their output would be treated. The methodclogies employed for implementing the algorithms would be consistent with AI/Expert System practice.

FIGURE 11

	Start Work 5/2/88	Interim Demo #1 2/28/89	Interim Demo #2 4/28/89	Interim Demo #3 5/26/89	Interim Demo #4 6/30/89	Proof of Concept Demo 7/28/89
Algorithms						
Collision Avoidance	X	X	X	X	X	X
Course Following	X		X	X	X	X
Safe Spacing	X			X	X	X
Low Fuel	X				X	X
Diversion/Field	X					X
Interactive Simulation						
Phased Implementation	X	X	X	X	X	X
Message Generator						
Phased Implementation	X	X	X	X	X	X
ATALARS Database	X	X	X	X	X	X

ATALARS Phase II Schedule

This is because it is expected that ATALARS will evolve as an AI based system. Development costs would preclude a rigorous AI (LISP) implementation of the algorithms in Phase II, primarily because the EJSE's current JTIDS message handling capabilities would be impacted. However, the next stage in development would include adding a separate LISP based algorithm processor to the EJSE.

3.3.2 **Message Generation**. The next step is to establish automatic message generation routines in the Display Group. This module will become the interface between the ATALARS Processor and the controlled aircraft, real or simulated. In response to a command, either from the EJSE operator of from the ATALARS processor, the message generator will construct the desired JTIDS message and transmit it. It would also include an optional mode of operation where, if selected, the message would be displayed for EJSE operator review and transmitted upon his release. The additions will include automating the composition and release of JTIDS command messages, which are presently accomplished by a series of operator interactions with menus shown on the Disply Function Panel.

3.3.3 **ATALARS Database**. The existing EJSE Display Group contains database functions that support the various DP activities. It handles static files, such as map displays, as well as dynamic files, such as trajectory and addressed message data. ACSI would use these functions as the starting point to develop the ATALARS Data Base functions that will receive, store and provide the information necessary to support the ATALARS algorithms, and to assure that the right information is kept and maintained. Development would begin with the data elements shown in Table VIII.

3.4 Simulation Group Modification

The Simulation Group of the EJSE must be made interactive to permit use of the EJSE for a Proof of Concept demonstration. Specifically, the Simulation Group must be able to cause a

TABLE VIII

ATALARS DATABASE
FOR
PROOF OF CONCEPT DEMONSTRATION

Static Files

Approach Plate Information
- 4 Airfields
- 2 Runways/Airfield

Flight Characteristics
- F-15
- F-16
- Fuel Burn Rate vs Speed & Altitude
- Rates of Turn
- Rate of Ascent/Descent

Separation Requirements

Dynamic Files

Flight Plan/Mission Briefing
- Route/Timing
- Controlling Unit Changes
- Primary Recover Field
- Alternate Recover Field

Aircraft PPLI
- Position
- Altitude
- Speed
- Heading
- Track Number

Aircraft Status
- Fuel Remaining

Airfield Status
- Open/Closed
- Runway in Use
- Landing Queue

simulated aircraft to receive and respond to an addressed message without intervention by the EJSE operator. For example, if the EJSE operator initiates a vector message from the Display Group to a specified simulated element telling it to change course, the operator would see the acknowledgment and subsequent course change by that element without further interaction with the EJSE. In addition to the logic required to respond to messages, a database of performance characteristics (such as rates of turn, climb, descent, acceleration and deceleration) of each simulated aircraft will be created.

The Simulation Tape Generation (STG) function of the existing Modular Control Equipment (MCE) Baseline EJSE would be used without modification to generate a scenario Data Base Generation (DBG) data base on disk. The Simulation Processor (SP) would be modified to read this DBG data base into its memory in a pre-start mode. This will serve as the starting point for the demonstration scenario.

Next, the SP would be modified to include a function analogous to the existing Tape Generation function, but would send PPLI and Track messages to the Display Processor (DP) in real time. Finally, the SP would be modified to accept command messages sent to it by the DP and to respond to them as follows:

- Run the DBG database for the affected element(s) through a function similar to DBG for the new parameters.
- Rearrange events in the simulation as necessary.
- Provide for smooth turns and trajectory changes.
- Send out the resulting PPLI and Track messages based on the changes to the element profiles.

Modifications to the SP for the proof of concept demonstration would be accommodated to the following extent:

- Only selected JTIDS messages and fields will be implemented.
- There will be no print function at the SP (not

required for interactive simulation).

- o A maximum of ten messages per second will be sent to the LAN by the SP in the mode.

- o The SP will be set up initially to handle not more than 30 JTIDS elements interactively.

3.5 Technical Report

In addition to the demonstrations, ACSI will prepare interim and final technical reports. The reports will cover the activities described above, with their actual outcomes. The reports will also provide an assessment of the aspects of the ATALARS concept covered in the study. The final report will contain a proposed work plan for the next stage in the development of ATALARS.

3.6 Additional Features

There are several directions in which investigations could proceed after the Proof of Concept demonstration. The potential extensions tend to fall into groups.

3.6.1 Algorithm Additions. The first group consists of additions to the set of algorithms. It is likely that each of the algorithms created will have places where additional operational contingencies can be addressed. One or more of the algorithms would be selected for review and further expansion in the ATALARS processor.

3.6.2 Scenario Additions. Another group would be additions to the scenario. More controlled aircraft could be added, providing the capability to refine estimates of the volume of processing and message traffic required to support ATALARS. One or more helicopters could be added, to highlight the differences in control requirements. Interaction with friendly SAM batteries would serve to highlight the interoperability features.

3.6.3 Presentation Enhancements. The last group of features which would enhance presentations of the Proof of Concept

Demonstration. By setting up a second display and creating an appropriate window, the cockpit display could be shown next to the ground controller display. This would give a good picture of the interaction between the pilot and controller. The EJSE could also be modified so that fuel remaining and other status parameters relevant to ATC could be shown in the tabular display. This capability would help an observer see when a change in a flight parameter precipitates a recommendation for change resulting from one of the algorithms. Finally, ACSI could set up the EJSE and provide support for a demonstration of the ATALARS concept using live JTIDS platforms.

3.6.4 Artificial Intelligence Enhancements. As part of the transition from Phase II to Phase III, a powerful PC based tool should be created to be used to develop and demonstrate the AI portions of the concept. It would handle some of the ATC algorithms, and show simulated tracks and map data, but would not be able to process JTIDS messages or model the GCU man-machine interface like the EJSE. It would consist of a state of the art 32 bit microprocessor (such as Intel 80386 or Motorola 68020 or 68030) based microcomputer with the added capability to handle LISP programs. Early in Phase III, or after the proof of concept demonstration in Phase II, this system could be connected to the EJSE's Display Group as a first step in developing the GCU architecture. This would allow the ATC algorithm processing, or AI functions for ATC, to be handled as a single piece of a distributed processing environment.

4.0 LIST OF REFERENCES

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JINTACCS (Joint Interoperability of Tactical Command and Control Systems) JTIDS (Joint Tactical Information Distribution System) Technical Interface Design Plan, Revision 1, Change 1 dated July, 1986 by Joint Tactical Command, Control and Communications Agency (JTC^{3}A)

System Segment Specification for the AN/UYQ-44 (Enhanced JTIDS System Exerciser) (Specification No. TCS 85S 2050 B) dated 26 March 1987.

5.0 GLOSSARY

ACK	Acknowledge (receipt of a message)
ACSI	Analysis and Computer Systems, Inc.
AGL	Above Ground Level
AI	Artificial Intelligence
AIM	Airman's Information Manual
ATALARS	Automated Tactical Aircraft Launch and Recovery System
ATA	Airport Traffic Area
ATC	Air Traffic Control
AWACS	Airborne Warning and Control System
CAS	Close Air Support
CRC	Combat Reporting Center
C3	Command, Control, Communications
DBMS	Data Base Management System
DG	Display Group
DH	Decision Height
EAC	Expected Approach Clearance
EJSE	Enhanced JTIDS System Exerciser
EMCON	Emission Control
ESD	Electronic Systems Division (of Air Force Systems Command)
FAF	Final Approach Fix
FAR	Federal Aviation Regulations
FEBA	Forward Edge of Battle Area
FL	Flight Level (feet x100)
FLIP	Flight Information Publications
FLOT	Forward Line of Own Troops
GCU	Ground Control Unit
GPS	Global Positioning System
IAF	Initial Approach Fix
IAP	Instrument Approach Procedures
IFF	Identification Friend or Foe
IFR	Instrument Flight Rules
IJMS	Interim JTIDS Message Set
JTIDS	Joint Tactical Information Distribution System

GLOSSARY - (Cont'd)

L/D Max	Maximum Lift/Drag
LAN	Local Area Network
MAP	Missed Approach Point
MCE	Modular Control Equipment
MLS	Microwave Landing System
MOA	Military Operations Area
MRC	Minimum Risk Corridor
MSG	Message
MSL	Mean Sea Level
PPLI	Precise Participant Location & Identification
POS	Preliminary Operational Scenarios
RPV	Remotely Piloted Vehicle
SAM	Surface to Air Missile
SBIR	Small Business Innovation Research
SG	Simulation Group
SIF	Selective Identification Feature
TACS	Tactical Air Control Systems
TADIL	Tactical Data Information Link
TCA	Terminal Control Area
TDMA	Time Division Multiple Access
TDZ	Touchdown Zone
TG	Terminal Group
TIDP	Technical Interface Design Plan
TOA	Time of Arrival
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
V_{MO}	Maximum Speed
V_{SO}	Stall Speed